VIRGINIA GEOLOGICAL SURVEY

UNIVERSITY OF VIRGINIA

THOMAS LEONARD WATSON, PH. D.
DIRECTOR

Bulletin No. IV

THE

Physiography and Geology of the Coastal Plain Province of Virginia

BY

WILLIAM BULLOCK CLARK AND BENJAMIN LEROY MILLER

WITH CHAPTERS ON

The Lower Cretaceous

BY EDWARD W. BERRY

AND

The Economic Geology

BY THOMAS LEONARD WATSON

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Virginia Geological Survey,
University of Virginia,
Charlottesville, January 20, 1912.

To His Excellency, Hon. Wm. Hodges Mann, Governor of Virginia, and Chairman of the State Geological Commission:

Sir:—I have the honor to transmit herewith for publication, as Bulletin No. IV of the Virginia Geological Survey Series of Reports, a report on "The Physiography and Geology of the Coastal Plain Province of Virginia," by Professors Wm. Bullock Clark and Benjamin LeRoy Miller, with a chapter on the "Economic Products," by Thomas Leonard Watson, State Geologist.

The investigations embodied in this report have been conducted by the Virginia Geological Survey in coöperation with the U. S. Geological Survey, with Dr. T. Wayland Vaughan of the U. S. Geological Survey as supervising geologist in charge of the work.

Respectfully submitted,

Thomas L. Watson,
Director.

PREFACE

This report contains a discussion of the physiography and geology of the Coastal Plain province of Virginia. All of the formations here represented are found in adjacent states either to the north or to the south. The Virginia region is classic ground for the student of Atlantic Coast Tertiary geology, while the Cretaceous deposits are also well known. There are few portions of the Coastal Plain that have received more attention, although the greater portion of the work done in Virginia dates from an early period when individual sections were studied and their fossil contents collected and discussed. Little was done at that time toward delimiting either the formational units or their areal distribution, while the broader physiographic problems were quite untouched. The present investigation has endeavored to cover these larger problems. The work has been carried on in conjunction with similar studies in Maryland and North Carolina.

The first chapter, entitled *Physiography of the Virginia Coastal Plain*, deals with the surface features of the district, which consist mainly of a series of dissected terraces formed during late Tertiary and Quarternary times. The similarity of this region to the adjoining areas in Maryland and North Carolina is clearly shown.

The second chapter, entitled *Geology of the Virginia Coastal Plain*, comprises an exhaustive study of the character and distribution of the formations of eastern Virginia. This investigation began nearly twenty years ago, when the senior author of this report started his study of the geology and paleontology of the regions bordering the main drainage lines of the district. Excursions covering longer or shorter intervals were made yearly from that time forward. In later years the junior author of this report has spent much time in the field mapping the limits of the several formations, and in making still further paleontological collections. As the result of the prolonged investigation to which the district has been subjected, the authors of this report are able to present much in the way of detailed results.

The authors have been materially aided in the study of the Lower Cretaceous formations by Mr. E. W. Berry, of the Johns Hopkins University, who has spent much time in the field studying the detailed stratigraphy of these formations, and in collecting the fossil plants, a thorough revision at the same time being made of the specific determinations of his predecessors. Mr. Berry is the author of the section on the Lower Cretaceous. Dr. M. W. Twitchell, of South Carolina University, did much valuable work as an assistant in the study of the Miocene formations in several of the southern counties of the State. Miss Julia A. Gardner, of the Johns Hopkins University, has devoted much of her time for the past two years to a study of the Miocene faunas, more especially to the mollusca, which

are very extensively represented, and which furnish the best criteria for the recognition of the Miocene formations. The senior author of this report has also been engaged in a study of the Eocene fauna, to which he has long given much attention.

These studies, together with others which have been undertaken by specialists in other groups, will afford the materials for a series of systematic reports on the geology and paleontology of the Coastal Plain of Virginia, which will follow the present contribution as rapidly as possible.

The third chapter deals with the *Geological History of the Virginia Coastal Plain.* The various geological events which have transpired in Virginia during the building up of the Coastal Plain series of deposits are discussed, and the relationships of these events to the history of the entire Coastal Plain is considered.

The fourth chapter deals with the *Correlation of the Virginia Coastal Plain* formations, comparisons being instituted with the known horizons of adjacent states, as well as the hitherto recognized series of the Gulf, and even in some instances with European deposits.

The authors desire to express their obligations to Messrs. E. W. Berry and L. W. Stephenson, who have been carrying on an exhaustive field investigation of the Coastal Plain formations of the South Atlantic and Gulf states under the direction of Dr. T. Wayland Vaughan. This work has resulted in clearing up many disputed points, but the final results are not yet available for use in the present report.

The fifth chapter, entitled *Economic Products of the Virginia Coastal Plain,* by the State Geologist, embraces a discussion of the more important products of commercial value found in the various formations of eastern Virginia. Many undeveloped resources are found in this district, and attention is briefly directed to them in this connection.

Thanks are particularly due to the U. S. Geological Survey in coöperation with whom this investigation has been conducted. This report is one of a series being prepared by the Federal and State Surveys on the geology and water resources of the Coastal Plain under the supervision of a joint committee consisting of members of the U. S. Geological Survey and the State Geologists of the states involved, of which Dr. Wm. Bullock Clark, of the Johns Hopkins University, is chairman. Dr. Clark has under his direct charge the study of the district extending from North Carolina to New England. Dr. T. Wayland Vaughan, of the U. S. Geological Survey, is supervising geologist in charge of the entire work.

THOMAS L. WATSON,
Director.

THE PHYSIOGRAPHY AND GEOLOGY OF THE COASTAL PLAIN PROVINCE OF VIRGINIA

BY WM. BULLOCK CLARK AND BENJAMIN LE ROY MILLER.

INTRODUCTION

Geographers have long recognized three physiographic regions within the Middle Atlantic slope. They are known, beginning on the west, as the Appalachian Mountains, the Piedmont Plateau, and the Coastal Plain. While each one of these regions has its own peculiar characteristics, it nevertheless passes into that adjoining by insensible gradations.

The Appalachian Mountain region is composed of flat-topped ridges separated by deep, steep-sided and flat-bottomed valleys which have been carved from folded beds of limestone, sandstone, and shale of Paleozoic age.

The Piedmont Plateau exhibits a rolling surface which, along its eastern margin, is dissected by deep river gorges. It consists of metamorphosed sediments of pre-Cambrian and early Paleozoic age, into which great masses of igneous rocks have been injected. Overlying these ancient rocks in certain regions are Triassic beds which are in turn cut by eruptive rocks. The structure of the Piedmont Plateau is exceedingly complicated and has only been thoroughly worked out in a few regions.

The Coastal Plain also has a rolling topography along its western margin, where it blends with the Piedmont Plateau, but throughout most of its eastern half it is flat and featureless. The deposits of the Coastal Plain are much younger than those of the other two regions and consist of unconsolidated sediments of late Mesozoic and Cenozoic age which have suffered few disturbances since their deposition.

The boundary of the Atlantic Coastal Plain to the eastward is marked by the well-defined scarp of the continental shelf which, off the Virginia coast, lies from 30 to 50 miles to the eastward of the present shore-line. It forms an escarpment along the western portion of the true oceanic basin with a height of from 5,000 to 10,000 feet or more. By common practice the 100-fathom line is regarded as the boundary of the continental shelf although the depth of the water is often nearly twice that amount where the abrupt change occurs. The descent of the slope to the greater ocean depths is rapid; at Cape Hatteras there is an increase in depth of 9,000 feet in 13

miles, a grade as steep as that often found along the flanks of the greater mountain systems. In striking contrast to this declivity is the comparatively flat ocean bed stretching away to the east, with but slight differences in elevation. Looked at from the base the escarpment would have the appearance along its crest of a high mountain range with a very even sky line. Here and there notches would be seen, produced by the streams which once flowed across the continental shelf, but there would be no peaks or serrated ridges.

The western limit of the Atlantic Coastal Plain is defined by a belt of crystalline rocks, consisting of greatly metamorphosed igneous and sedimentary materials, ranging in age from the pre-Cambrian to the Silurian period. These rocks form the eastern portion of the Plateau province. Most of the larger streams and many of the smaller ones, as they cross the western margin of the Coastal Plain, are characterized by falls or rapids and always show a marked decrease in the velocity of their currents, the name "fall-line" being given to this boundary on that account. The position of the "fall-line" near the head of navigation or near the source of water-power has been one of the very important factors in determining the location of many of the towns and cities of the Atlantic coast; Newark, Trenton, Philadelphia, Wilmington, Baltimore, Washington, Fredericksburg, Richmond, Petersburg, Raleigh, Camden, Columbia, Augusta, Macon, and Columbus being located on this boundary. A line drawn through these places would approximately separate the Coastal Plain from the Piedmont Plateau. Along the eastern margin of the Piedmont district outliers of the Coastal Plain are frequent, while along the valleys of the larger streams the crystalline rocks can at times be followed for a mile or more into the body of the Coastal Plain sediments where the mantle of the latter has been cut through.

The Atlantic Coastal Plain is divided into two parts by the present shore-line, a submerged or *submarine* portion known as the continental shelf, or continental platform, and an emerged or *subaerial* portion commonly called the Coastal Plain. In some places the division line is marked by a sea cliff of moderate height, but usually the two grade into each other with scarcely a perceptible change, and the only mark of separation is the shore-line. The areas of the respective portions have changed frequently during past geologic time by the shifting of the shore-line eastward or westward, due to local and general depressions or elevations of greater or less extent, and even at the present time such changes are in progress. Old river valleys, the continuations of channels of existing streams, have been traced entirely across

the continental shelf at the margin of which they have cut deep gorges. The Hudson River channel is particularly well marked and has been shown to extend almost uninterruptedly to the edge of the shelf over 100 miles to the east of its present mouth. The same is true of Chesapeake Bay. This sheet of water so broad and deep to-day and affording the great highway of commerce for Virginia's export trade as well as the unparalleled local transportation facilities for the tidewater country, is the submerged lower valley of the old Susquehanna River which flowed across Maryland and Virginia and found its way seaward past the Capes, its channel continuing across the sea floor of the submarine portion of the Coastal Plain.

The combined width of the submarine and subaerial portions of the Coastal Plain province is quite uniform along the entire eastern border of the continent, being approximately 250 miles. In Florida and Georgia the subaerial portion is over 150 miles wide, the eastern submerged portion being much narrower, and along the southeastern shore of the peninsula of Florida it is almost wanting. Northward the submerged portion gradually increases in width, while the subaerial portion becomes narrower. Except in the region of Cape Hatteras, where the submarine belt becomes narrower with a corresponding increase in width of the subaerial belt, this gradual change continues as far as the southern part of Massachusetts, beyond which the subaerial portion disappears altogether through the submergence of the entire Coastal Plain province. Off Newfoundland the continual shelf is about 300 miles in width.

The surface of the Coastal Plain has a gentle slope from the "fall-line" to the east, gradually declining eastward from five feet to the mile to one foot or even less, except in the vicinity of the Piedmont Plateau, where the slope is occasionally as great as 10 to 15 feet to the mile and in a few instances even more rapid. The submerged portion which slopes even less rapidly eastward is monotonously flat as desposition has destroyed most of the irregularities produced by erosion when it formed a part of the land area. The slight elevation of the subaerial portion which seldom reaches 400 feet, and is for the most part less than half that amount, has prevented the streams from cutting valleys of great depth. The country, however, in the vicinity of the larger streams shows considerable relief, although the variations in altitude are only a few hundred feet. Throughout a great portion of the area this relief is very inconsiderable, the streams flowing in open valleys at only a slightly lower level than the broad flat divides.

The land portion, or the subaerial division, of the Coastal Plain province is marked by the presence of many bays and estuaries, representing sub-

merged valleys of streams carved out during the time when the region stood at a higher level than at present. Chesapeake Bay, which is the old valley of the Susquehanna River, and Delaware Bay, which is the extended valley of the Delaware River, together with such tributary streams as the Patuxent, Potomac, York, and James rivers are examples of such bays and estuaries, of which there are many others of less importance. The streams which have their sources in regions to the westward are almost invariably turned in a direction roughly parallel to the strike of the formations as they pass out into the Coastal Plain. This is well shown in the case of the Potomac and James rivers which at Washington and Richmond suddenly change their courses and flow in an almost southerly direction for several miles. With this exception the structure of the formations and the character of the materials have had little effect upon stream development except locally.

The materials of which the Coastal Plain is composed consist of boulders, pebbles, sand, clay, and marl, mostly loose or locally indurated. In age the formations range from Lower Cretaceous to Recent. Since the time when the oldest formations of the province were formed there have been many periods of deposition alternating with erosion intervals. The sea, however, advanced and retreated differently in various parts of the region, so that at the present time few of the formations can be traced by outcropping beds throughout the entire area. Different conditions thus prevailed and great variability in the deposits has been produced during each period.

The Virginia Coastal Plain occupies the eastern portion of the State and has an area of somewhat more than 14,000 square miles, of which about 10,000 square miles belong to the subaerial division or Coastal Plain proper, and about 4,000 square miles to the submarine division. In the former are also included the estuarine waters of the lower Chesapeake Bay with the tributaries of the Rappahannock, York, James, and other rivers, which together have an area of about 3,000 square miles. The Coastal Plain proper forms about one-fourth of the entire area of the State. On account of the tidal bays and estuaries which traverse it in all directions it has received the name of "tide-water Virginia" and its nearly 2,000 miles of shore-line is bordered at almost all points by navigable waters.

To the north and south the Coastal Plain of Virginia is continuous with the Coastal Plain regions of Maryland and North Carolina; to the east the region is bounded by the basin of the Atlantic Ocean; and to the west a much more irregular and less easily determined line separates it from the Piedmont Plateau. The difficulty in drawing the westward limiting line is due to the relations existing between the formations of the two regions, the

Coastal Plain deposits resting upon an uneven eastward-sloping floor of Piedmont Plateau crystalline rocks. In the depressions of this floor much thicker deposits accumulated than in other places. Everywhere also the deposits thin out toward the west and, since the deposition of the beds, erosion has in many places destroyed the continuity of the mantle of unconsolidated materials. Thus outliers of Coastal Plain sediments, separated from the continuous cover by miles of intervening crystalline rocks, are common.

The deposits of the Lafayette formation particularly are frequently found overlying the Piedmont crystallines as isolated patches many miles beyond the limits of the great mass of Coastal Plain sediments. A few miles to the west of Falls Church in Fairfax County is a striking instance of such an outlier of Coastal Plain deposits, covering several square miles, and separated from the continuous mantle farther east by a distance of quite five miles. A similar outlier of considerable extent occurs near the small village of Midlothian in the northwestern part of Chesterfield County. Several miles of crystalline rocks intervene between it and the main body of the Coastal Plain deposits. Many such Coastal Plain outliers of large and small extent occur throughout the eastern part of the Piedmont Plateau. They furnish evidence of a former much more extensive Coastal Plain whose marginal deposits have been largely removed by erosion, leaving only small remnants over the divides or in places where, on account of depressions, the deposits were unusually thick. The present streams which have cut through the thin marginal strata have exposed the underlying crystalline rocks at times many miles to the east of the points where they are still concealed from view on the uplands of the stream divides. Along the larger streams these crystalline rocks disappear near the level of tide. Even disregarding the outliers mentioned above, the boundary line between the Piedmont Plateau and the Coastal Plain in Virginia is a very irregular line running in a general north and south direction but bending eastward in the valleys of all the eastward-flowing streams and westward over the intervening divides.

Along the Potomac River the crystalline rocks finally disappear at Washington; along the Rappahannock they are not seen to the east of Fredericksburg; along the James River they disappear at Richmond, but because of great irregularity in the crystalline floor or on account of post-Tertiary disturbance, they again appear in one place a short distance above Dutch Gap canal; while along the Meherrin River the crystalline rocks disappear below water level a short distance below Emporia. Over the

divides the continuous cover of Coastal Plain sediments extends from three to ten miles farther to the west. Geographically, the westward limiting line of the Coastal Plain of Virginia passes through the eastern part of Fairfax, Prince William, Stafford and Spottsylvania counties, the extreme western part of Caroline County, the central part of Hanover, Henrico, and Chesterfield counties, the eastern part of Dinwiddie County, the western part of Sussex County, and the eastern part of Greenesville County.

GEOLOGICAL LITERATURE OF THE VIRGINIA COASTAL PLAIN

1783

LINCOLN, GEN. BENJ. An account of several strata of earth and shells on the banks of York River, in Virginia.

Mem. Amer. Acad. Arts and Sci., vol. i, pt. ii, pp. 372-373, 1783.

This is the earliest known reference to the geology of the Coastal Plain of Virginia and for that reason the article is quoted in its entirety. "That this earth, since its formation, has met with great changes, and that the shores, now covered with the tallest cedars and most luxuriant plants, were once washed by the ocean, none can deny. The land between *James-river* in *Virginia*, is very level; its surface being about forty feet above high-water mark. It appears to have arrived to its present height at different periods, far distant each from the other, by means of the ocean: for, near *York-town*, where the banks are perpendicular, you can first see a stratum of earth, about five feet high, intermixed with small shells, which has the appearance of a mixture of clay and sand. On that lies, horizontally, a stratum of white shells, the cockle, the clam, and others, an inch or two thick; then a body of earth, similar to the first mentioned, eighteen inches thick; and on that lies another thin body of small shells, then a third body of earth, about the same thickness as the last; and on that lies another body of white shells, of various kinds, about three feet thick, with very little sand, or earth, mixed with them. On these lies a body of oyster-shells, about six feet thick; then a body of earth to the surface. The oyster-shells are so united by a very strong cement, that they fall only when undermined, and then in large bodies, from one to twenty tons weight. They have the appearance of large rocks on the shores and are wasted by the frequent washing of the sea. All these different strata seem to be perfectly horizontal.

"After riding about seven miles from *York-town*, near the center between the two rivers, I discovered, at a place from which a large body of earth had been removed to a mill-dam, nearly the same appearance as in the bank first mentioned.

"What they call their stone, with which they build in *York-town* is nothing more than shells, united by a strong cement, which seems to be petrified in a degree, but is apparently affected by the weather."

1799

LATROBE, B. HENRY. Memoir on the Sand-hills of Cape Henry in Virginia.

Trans. Amer. Phil. Soc., vol. iv, pp. 439-444, Phila., 1799.

The aqueous origin of the Coastal Plain is advocated in the following statements: "That the whole of this extensive country, from the falls of the coast, is factitious, and of Neptunian origin, appears far from being hypothetical; and the fossil teeth and bones (shark's teeth, fish vertebræ, etc.) which accompany this memoir, and which with many hundred more, were dug out of a well at Richmond, from the depth of 71 feet, prove that the deposition of the superstrata is not of a date sufficiently removed to have destroyed the soft and almost cartilaginous part of the joints, or to have injured the enamel of the teeth. The Neptunian theory of geogeny, has now very generally taken the place of the old volcanic system, and, as far as conjecture and hypothesis can forward science, it is certainly more generally applicable."

A very good account of the Cape Henry sand hills is given. From the description it is evident that the sand dunes have changed very little during the past hundred years, although Latrobe found that the growth and advance of the sand dunes had been comparatively rapid for some time previous to his observations.

1809

LATROBE, B. H. An account of the Freestone quarries on the Potomac and Rappahannock rivers. Read Feb. 10, 1807.

Trans. Amer. Phil. Soc., vol. vi, pp. 283-293, Phila., 1809.

The quarries of Potomac sandstone near the mouth of Aquia Creek and on the Rappahannock River near Fredericksburg are described. Latrobe likened the deposits to the sand dunes at Cape Henry and suggested a common origin for both deposits. He supposed that at one time the Potomac sands were beach dunes which had been heaped up by the wind.

MACLURE, WILLIAM. Observations on the Geology of the United States, explanatory of a Geological Map. Read Jan. 20, 1809.

Trans. Amer. Phil. Soc., vol. vi, pp. 411-428, map. Phila., 1809. Republished with additions in 1817 and 1818.

A general account of the geology of the United States in which the limits of the Atlantic Coastal Plain are roughly defined and the Coastal Plain deposits briefly described under the title of the "Alluvial Formation."

1818

MITCHELL, SAMUEL L. Observations on the Geology of North America, illustrated by the description of various organic remains found in that part of the world.

Cuvier's Essay on the Theory of the Earth, pp. 319-424, 3 pls., New York, 1818

Mention is made of vertebrate bones and teeth found in Richmond of the ribs and vertebræ of a whale found near Williamsburg in 1802, and the remains of a mammoth found in 1811 on the York River about 6 miles east of Williamsburg. The Richmond fossils were probably from the Aquia, the Williamsburg ones from the St. Mary's or Yorktown, and the bones of the mammoth from the Talbot.

1824

FINCH, JOHN. Geological Essay on the Tertiary Formations in America. Read before the Acad. of Nat. Sci. at Phila., July 15, 1823.

Amer. Jour. Sci., vol. vii, pp. 31-43, New Haven, 1824.

In this article the writer objects to the term "Alluvial" being used to include all the Coastal Plain formations and advocates the separation of the Tertiary formations from the alluvial beds. He correlates the fossiliferous beds at Richmond (Eocene?) and Williamsburg (Miocene) with the London Clay.

1826

PIERCE, JAMES. Practical remarks on the shell marl region of the eastern parts of Virginia and Maryland, and upon the bituminous coal formation in Virginia and the contiguous region.

Amer. Jour. Sci., vol. ii, pp. 54-59, New Haven, 1826.

The wide distribution of rich shell marl "of marine origin" throughout the Coastal Plain of Virginia and Maryland is mentioned and the writer advocates the use of the material as a fertilizer on exhausted soils. Cases are cited where the soil was rendered much more productive by the addition of a thin layer of the shell marl.

1832

CONRAD, T. A. Fossil Shells of the Tertiary Formations of America. Vol. i, Nos. 1-3, 56 pp., 20 pls., Phila., 1832-35. Republished by G. D. Harris, Washington, 1893.

In this work molluscan fossils are described from Yorktown, Smithfield, and Suffolk. In the first part (No. 1) of the work the deposits in eastern Virginia are designated as the Upper Marine or the Upper Tertiary while in the last part (No. 3) the same deposits are called Medial Tertiary or Older Pliocene. In this latter part the Eocene is mentioned as occurring in Virginia "forming the western boundary of the Pliocene."

1833

CONRAD, T. A. On some new Fossil and Recent Shells of the United States.

Amer. Jour. Sci., vol. xxiii, pp. 339-346, 1835.

Several new species of fossils from Yorktown, Suffolk, and Smithfield are described from the "upper marine" (Miocene) formation.

1834-5

CONRAD, T. A. Observations on the Tertiary and more Recent Formations of a Portion of the Southern states.

Jour. Acad. Nat. Sci., Phila., vol. vii, pp. 116-129, 1834.

The occurrence of the Eocene and "Pliocene" (Miocene) is noted along the James River and the statement is made that the "Pliocene" deposits there contain *Ostrea compressirostra*.

ROGERS, WM. B. Some observations on the Tertiary Marl of Lower Virginia. The Farmers Register, 1834-5. Reprint of Report on the Geology of the Virginias, pp. 1-20, New York, 1884.

In a letter to the editor of the *Farmer's Register* dated June 26, 1834, Professor Rogers reports the presence of greensand near Williamsburg, Kings Mill, and at Bellefield, which he was hopeful would furnish as good greensand for fertilizing purposes as that of New Jersey. In the *Farmer's Register* for 1835 the value of the shell marls near Williamsburg and Yorktown for fertilizing purposes is discussed. The writer follows Conrad in placing the Yorktown, James River, Smithfield, and Suffolk beds in the Middle Tertiary. He also reports the presence of the Lower Tertiary or Eocene in Virginia along the Potomac, Rappahannock, Pamunkey, and James rivers and described its lithologic characters. *Cardita planicosta, Ostrea sellæformis,* and *Fusus longævis* are said to occur in great numbers in all localities examined and the entire fauna shows marked relationships to the Eocene of Alabama, Paris and London. The greensand and gypsum of the Eocene deposits are both said to be valuable for fertilizing purposes.

1835

Clemson, Thomas G. Notice of a Geological Examination of the Country between Fredericksburg and Winchester in Virginia, including the Gold Region.

Trans. Geol. Soc. of Penn., vol. i, pp. 298-313, Phila., 1835.

The lithological characters of the Potomac deposits in the region of Fredericksburg are described.

Conrad, T. A. Observations on a Portion of the Atlantic Tertiary Region.

Trans. Geol. Soc. of Penn., vol. i, pp. 335-341, pl. 13, Phila., 1835.

The contact between the Eocene and "older Pliocene" (Miocene) is noted as exhibited on the James River near City Point and again at Coggin Point. A species of coral from the Miocene of Virginia is described and figured.

——— Observations on the Tertiary Strata of the Atlantic Coast.

Amer. Jour. Sci., vol. xxviii, pp. 104-111, 280-282, 1835.

The beds at Yorktown, on the James River near "Smithfall" (Smithfield ?) and Suffolk, are referred to the Medial Pliocene, which formation is characterized by the presence of 30 per cent. of living species in the fossil fauna. The beds now referred to the Calvert, Choptank, and St. Mary's formations are termed "Older Pliocene" and are characterized by numerous specimens of *Perna maxillata* and a few living species. The Miocene is said to be "probably wanting."

Taylor, Richard C. Notice of Certain Fossil Acotyledonous Plants in the Secondary strata of Fredericksburg.

Trans. Geol. Soc. of Penn., vol. i, pp. 320-325, pl. 19, Phila., 1835.

Six plants from the Potomac deposits are described and figured in this article.

1836

Rogers, William B. Report of the Geological Reconnaissance of the State of Virginia.

144 pp., 1 map, Phila., 1836.

Reprint of Reports on the Geology of the Virginias, pp. 21-122, New York, 1884.

The geographic distribution, the stratigraphic relations, and lithologic characters, the conditions of deposition, and the economic products of the Miocene and Eocene strata are all discussed. The superficial deposits of sands, gravels, indurated ferruginous sandstones, and ochreous clays are described from the Middle Tertiary (Miocene) district but are not separated from the Miocene strata.

1837

——— Report of the Progress of the Geological Survey of the State of Virginia for the year 1836.

22 pp. Richmond, 1837. Another edition, 14 pp. 4°, Richmond, 1837. Reprint of Reports on the Geology of the Virginias, pp. 122-145, New York, 1884.

The geographic distribution and lithologic characters of the Eocene and Miocene deposits occurring on the peninsula lying between the Potomac and Rappahannock rivers are described and the economic value of the greensand and shell marl deposits discussed.

ROGERS, W. B. AND H. D. Contributions to the Geology of the Tertiary Formations of Virginia. Read May 5, 1835.

Trans. Amer. Phil. Soc., vol. v (n. s.), 1837, pp. 319-341.

Reprinted in part in Geology of the Virginias, pp. 661-668, New York, 1884.

The character of the country and the geology of Elizabeth City, Warwick, York, and James City counties with parts of New Kent and Charles City counties are discussed at considerable length. The sections at Kings Mill and Yorktown are described in particular. The Miocene age is determined by the presence of only 19 per cent. of recent species found in the deposit at Kings Mill, where 74 species have been described. New species of Miocene fossils from Williamsburg and Prince George County are described.

The Eocene deposits on the James River together with some new species of Eocene fossils are briefly described.

The superficial deposits resting unconformably upon the Miocene are mentioned, but in the absence of fossils no conclusion is reached regarding their age.

1838

CONRAD, T. A. Fossils of the Medial Tertiary of the United States.

No. 1, 32 pp., 17 pls., Phila., 1838. Republished with an introduction by W. H. Dall, Phila., 1893.

The geographical limits of the formation, the lithologic characters of the strata, and the conditions of deposition are all described. The deposits are correlated with the Crag of England. Fossils from Yorktown, Smithfield, Suffolk, City Point, and Williamsburg are described and figured.

ROGERS, WM. B. Report of the Progress of the Geological Survey of the State of Virginia for the year 1837.

24 pp., 4°, Richmond, 1838. Reprint of Reports on Geology of the Virginias, pp. 145-188, New York, 1884.

The report contains partial analyses, giving the carbonate of lime content only, of over 150 specimens of Miocene and Eocene marls from the Coastal Plain counties. The non occurrence in Virginia of "secondary greensand (Cretaceous) beds, similar to those of New Jersey" between the Eocene and the "coarse conglomerates, sandstones, and clays which overlie the primary rocks" is expressly stated.

1839

CONRAD, T. A. New Species of Fossil Shells.

1 p., Phila., 1839. Republished by W. H. Dall, Phila., 1893.

New fossils from Urbanna, Yorktown and Smithfield are described.

ROGERS, W. B. AND H. D. Contributions to the Geology of the Tertiary Formations of Virginia. Second series. (Read March 1, 1839.)

Trans. Amer. Phil. Soc., vol. vi (n. s.), pp. 347-377, pls. 25-30, 1839. Reprinted in part in Geology of the Virginias, pp. 669-673, New York, 1884.

The topography and geology of the Northern Neck embracing the counties of Lancaster, Northumberland, Richmond, Westmoreland, and King George, and the eastern part of Stafford County are discussed and many outcrops of Miocene and Eocene strata described. A few new species of fossils from the Miocene and Eocene are described and figured.

——— Contributions to the Geology of the Tertiary Formations of Virginia. Second series.

Proc. Amer. Phil. Soc., vol. i, pp. 88-90, 1839.

Abstr. Amer. Jour. Sci., vol. xxxviii, pp. 183-184, 1840.

The geology of the peninsula embraced between the Potomac and Rappahannock rivers from Chesapeake Bay to the head of tidewater is described. The stratigraphy, lithology, and paleontology of the Eocene and Miocene strata are briefly described.

1840

Conrad, T. A. Fossils of the Medial Tertiary of the United States.

No. 2, pp. 33-56, pls. 18-29, Phila., 1840. Republished by W. H. Dall. Phila., 1893.

Miocene fossils from City Point, Smithfield, Yorktown, Suffolk, Urbanna, and Lancaster counties are described and figured.

Lea, Henry C. Description of some new Fossil shells from the Tertiary of Petersburg, Va.

Trans. Amer. Phil. Soc., vol. ix, 1840, (n. s.), pp. 229-274, pls. 34-42.

One hundred and five new species are described and figured, making in all 173 species from the Miocene strata at Petersburg. Of these only nine can be identified with existing forms.

Rogers, Wm. B. Report of the Progress of the Geological Survey of the State of Virginia for the year 1839.

161 pp., 2 pls., Richmond, 1840. Reprint of Reports of the Geology of the Virginias, pp. 245-410.

The region lying south of the James River is discussed in great detail and the physiography, stratigraphy, and lithology of the area are very accurately described. The structure of the Coastal Plain is discussed more fully than in any of the earlier reports. The escarpment lying to the west of the Dismal Swamp is said to represent an old sea cliff which separates the low-lying region of the Norfolk area from the higher-lying flat plain to the west.

1841

Hodge, James T. Observations on the Secondary and Tertiary Formations of the Southern Atlantic States with an appendix describing new shells by T. A. Conrad.

Abst. Amer. Jour. Sci., vol. xli, pp. 182-183, 332-448, pl. ii, 1841.

Trans. Assoc. Amer. Geol. and Nat., pp. 34, 35, 94-III, pl. v, Boston, 1843.

The Eocene marl exposures on the Rappahannock and Pamunkey rivers are described. and the use of the marl as a fertilizer is highly recommended.

ROGERS, WM. B. Report of the Progress of the Geological Survey of the State of Virginia for the year 1840.

132 pp., Richmond, 1841. Reprint of Reports on the Geology of the Virginias. pp. 411-535, New York, 1884.

The report contains detailed descriptions of the Miocene, Eocene, and Potomac (called Upper Secondary) strata of the Northern Neck. The stratigraphic relations and lithologic characters are very accurately described, while lists of the most abundant fossils are given. The Tertiary strata exposed in the valley of Shockoe Creek, Richmond, are also described.

1842

CONRAD, T. A. Observations on a Portion of the Atlantic Tertiary Region, with a Description of New Species of Organic Remains.

Proc. Nat. Inst. Promotion Sci., vol. i, pp. 171-194, pls. i-ii, Washington, 1842.

The geographic limits and stratigraphic relations of the Eocene and Miocene in Virginia are given. The presence of *Ostrea sellæformis* is employed to separate the Eocene from the Miocene.

LYELL, CHARLES. On the Tertiary Formations and their connection with the Chalk in Virginia and other Parts of the United States.

Proc. Geol. Soc. London, vol. iii, pp. 735-742, 1842.

Brief mention is made of the Eocene and Miocene strata of Virginia and their contained fossils.

TUOMEY, M. Discovery of a chambered Univalve Fossil in the Eocene Tertiary of James River, Virginia.

Amer. Jour. Sci., vol. xliii, 1842, p. 187.

This article contains some conclusions of the author regarding the stratigraphy of the Eocene, based on a section exposed in a shaft sunk at Evergreen on the James River.

1843

CONRAD, T. A. Description of a New Genus and twenty-nine new Miocene and one Eocene Fossil Shells of the United States.

Proc. Acad. Nat. Sci., Phila., vol. i, pp. 305-311, 1843.

Six new species of Miocene fossils from Petersburg, Smithfield and James River are described.

——— Descriptions of Nineteen Species of Tertiary Fossils of Virginia and North Carolina.

Proc. Acad. Nat. Sci., Phila., vol. i, pp. 323-329, 1843.

Several new species of fossils from Petersburg, Coggins Point, and the Pamunkey River in Kent County, are described.

ROGERS, W. B. On Limits of Infusorial Stratum in Virginia.

Amer. Jour. Sci., vol. xlv, pp. 313-314, 1843.

In a letter the author reports that the infusorial stratum has been traced entirely across the state. In some places it rests upon the Eocene at other times upon Miocene. He therefore concludes that it should be referred to a position within and near the bottom of the Miocene, although he doubts whether the infusorial strata all occur at exactly the same horizon. Many imperfectly carbonized vegetable remains which "seem to be referable to creeping and cryptogamous plants" are reported to occur in great abundance at some localities.

TUOMEY, M. Notice of the Discovery of a new Locality of the "Infusorial Stratum."

Amer. Jour. Sci., vol. xliv, pp. 339-341, 1843.

The writer describes a deposit of the "infusorial stratum" within the city limits of Petersburg, 30 feet in thickness, and containing the casts of Pectens, resting upon the Eocene. The author definitely refers the infusorial stratum to the Miocene and correlates it with the Richmond bed on the basis of the microscopic fossils.

1844

BAILEY, J. W. Account of some new Infusorial Forms Discovered in the Fossil Infusoria from Petersburg, Va., and Piscataway, Md.

Amer. Jour. Sci., vol. xlvi, pp. 137-141, pl. iii, 1844.

Several new species are described and figured.

EHRENBERG, C. G. Ueber zwei neue Lager von Gebirgsmessen aus Infusorien als Meeres-Absatz in Nord Amerika und eine Vergleichung derselben mit den organischen Kreide-Gebilden in Europe und Afrika.

Bericht k. p. akad. Wiss., Berlin, pp. 57-97, 1844.

Review Amer. Jour. Sci., vol. xlviii, pp. 201-204, 1845, by J. W. Bailey.

The author describes 112 species of diatoms in the infusorial earth of Richmond, and 67 from the deposit at Petersburg, of which 46 are common to the two localities.

ROGERS, H. D. Address (on American Geology, and Present Condition of Geological Research in the United States).

Amer. Jour. Sci., vol. xlvii, pp. 137-160, 247-278, 1844.

A brief review of the geology of Eastern Virginia is given.

1845

BAILEY, J. W. Notice of some New Localities of Infusoria, Fossil and Recent.

Amer. Jour. Sci., vol. xlviii, pp. 321-343, pl. iv, 1845.

Gives tables of all known species then described from Petersburg and Richmond.

CONRAD, T. A. Fossils of the (Medial Tertiary or) Miocene Formation of the United States, No. 3.

Pp. 57-80, pls. 30-45, Phila., 1845. Republished by W. H. Dall, Washington, 1893.

Fossils from Petersburg, City Point, Prince George County, Ware River in Gloucester County, Pamunkey River in Kent County, Yorktown, Surrey County, Suffolk, and Urbanna, are described and figured.

LONSDALE, W. Indications of Climate Afforded by Miocene Corals of Virginia.

Quar. Jour. Geol. Soc., London, vol. i, pp. 427-429, 1845.

The author believes that the climate in the Virginia region during the Miocene was somewhat warmer than the present climate in the Mediterranean region.

LYELL, CHARLES. Observations on the White Limestone and other Eocene or Older Tertiary Formations of Virginia, South Carolina, and Georgia.

Quar. Jour. Geol. Soc., London, vol. i, pp. 429-442, 1845; Proc. Geol. Soc., London, vol. iv, pp. 563-575, 1845.

The author gives a description of the Eocene deposits of the James River, as well as of the Richmond and Petersburg areas. The occurrence of fossil species similar to Euorpean forms is mentioned.

——— On the Miocene Tertiary strata of Maryland, Virginia, and of North and South Carolina.

Quar. Jour. Geol. Soc., London, vol. i, pp. 413-427, 1845; Proc. Geol. Soc., London, vol. iv, pp. 547-563, 1845.

The author points out many similarities between the Miocene strata of Europe and North America in stratigraphic relations and fossil remains. Many localities on the James River where the strata are well exposed are described.

——— Travels in North America in the years 1841-2; with Geological Observations on the United States, Canada, and Nova Scotia.

2 vols., 12°, New York, 1845.

In a trip down the James River the author studied the Miocene deposits at Richmond, City Point, Evergreen, Grove Landing and Williamsburg. One hundred and forty-seven species of fossils were collected, most of which belong to genera recognized in the Miocene of Europe. Nine species are common to the two countries. The closer resemblance to the Miocene of the Loire and Gironde in France than to the Crag of England. is noted. A general description is given of the Dismal Swamp.

1846

CONRAD, T. A. Tertiary Fossil Shells.

Proc. Acad. Nat. Sci., Phila., vol. iii, pp. 19-27, 1 pl. 1846.

Two new species of Miocene shells from Suffolk and Yorktown and one Eocene fossil from City Point are described and figured.

CONRAD, T. A. Descriptions of eight new Fossil Shells of the United States.

Proc. Acad. Nat. Sci., Phila., vol. ii, pp. 173-174, 1846.

One Miocene shell from Petersburg and four Eocene forms from Hanover and Stafford counties are described.

1850

WYMAN, JEFFRIES. Notice of Remains of Vertebrated Animals found at Richmond, Virginia.

Amer. Jour. Sci. (n. s.), vol. x, pp. 228-235, 1850.

Bones of seals, whales, crocodiles, and many fishes are described from the Tertiary deposits along Shockoe Creek, Richmond. Most of them were probably derived from the Miocene strata, but some may have been contained in the Eocene deposits.

1852

LESQUEREUX, LEO. Ueber die Torfbildung un grossen Dismal-Swamp.

Geol. Gesell. Zeit., vol. iv, pp. 695-697, 1852.

The vegetation of the Dismal Swamp is described and the formation of the vegetable debris underlying the swamp discussed.

1853

CONRAD, T. A. Monograph on the genus Fulgur.

Proc. Acad. Nat. Sci., Phila., vol. vi, pp. 316-319, 1853.

Fulgur maximum and *F. incile* from Yorktown are described.

HITCHCOCK, EDWARD. Outline of the Geology of the Globe and of the United States in particular with two Geological maps, etc.

8°, Boston, 1853; 2d edit., 1854; 3d edit., 1856.

Brief descriptions of the Tertiary strata of Virginia are given.

MARCOU, JULES. A Geological Map of the United States and the British Provinces of North America with an explanatory text, etc.

8°, Boston, 1853.

Contains brief references to Virginia.

1854

WYMAN, JEFFRIES. Beak of a Fossil Fish (Icthiophorus) found in the Tertiary Deposit at Richmond, Va., communicated Oct. 6, 1852.

Proc. Boston Soc. Nat. Hist., vol. iv, p. 260, 1854.

Specimen said to resemble a sword-fish and probably belongs to undescribed species.

1856

EHRENBERG, C. G. Zur Mikrogeologie das Erden und Felsen Schaffende Wirken des unsichtbar kleinen selbstandigen Lebens auf der Erde.

2 vols. and atlas, roy. folio, 41 pls. Leipzig, 1854-56.

This work contains admirable descriptions and illustrations of over 100 species of diatoms from the infusorial earth of Richmond and other places in Virginia.

1861

CONRAD, T. A. Fossils of the (Medial Tertiary or) Miocene Formation of the United States.

No. 4, pp. 81-89, pls. 45-49. Index to parts 1-4, Phila., 1861 (?) Republished by W. H. Dall, Washington, 1893.

Fossils from Petersburg, Yorktown, Smithfield and Suffolk are described and figured.

ROGERS, W. B. Infusorial Earth from the Tertiary of Virginia and Maryland. (Read May 4, 1859.)

Proc. Boston Soc. Nat. Hist., vol. vii, pp. 59-64, 1861.

The stratigraphic relations, the lithologic characters, and the fossil contents of the diatomaceous earth strata exposed along Shockoe Creek, Richmond, are described in considerable detail.

1863

CONRAD, T. A. Catalogue of the Miocene Shells of the Atlantic Slope.

Proc. Acad. Nat. Sci., Phila., vol. xiv, pp. 559-582, 1863.

——— Descriptions of New, Recent, and Miocene Shells.

Proc. Acad. Nat. Sci., Phila., vol. xiv, pp. 583-586, 1863.

A few new Miocene shells from Virginia are described.

1864

MEEK, F. B. Check List of the Invertebrate Fossils of North America. Miocene.

Smith, Misc. Coll., vol. vii, No. 183, 34 pp., 1864.

1866

CONRAD, T. A. Illustrations of Miocene Fossils with Descriptions of New Species.

Amer. Jour. Conch., vol. ii, pp. 65-74, pls. 3, 4, 1866.

Some new species of shells from Smithfield, Yorktown, and James River are described and figured.

——— Descriptions of New Species of Tertiary, Cretaceous, and Recent Shells.

Amer. Jour. Conch., vol. ii, pp. 104-106, 1866.

Two new Miocene molluscan shells from Virginia are described.

CREDNER, HERMANN. Geognostische Skizzen aus Virginia, Nord Amerika.

Geol. Gesell. Zeits., vol. xviii, pp. 77-85, 1866.

Reference is made to the diatomaceous earth at Richmond, and the characteristics of the Dismal Swamp are described.

1867

GILL, THEODORE. On the Genus Fulgur and its Allies.
Amer. Jour. Conch., vol. iii, pp. 141-152, 1867.
References are made to several forms from the Miocene of Virginia.

1868

CONRAD, T. A. Descriptions of Miocene shells of the Atlantic Slope.
Amer. Jour. Conch., vol. iv, pp. 64-68, pls. 5, 6, 1869.
Several Miocene shells from Virginia previously described are re-classified, described, and figured.

——— Descriptions of New Genera and Species of Miocene Shells with Notes on other Fossil and Recent Species.
Amer. Jour. Conch., vol. iii, pp. 257-270, pls. 19-24, 1868.
Among the new forms described are several from the Miocene of Virginia.

COPE, E. D. Second Contribution to the History of the Vertebrata of the Miocene Period of the United States.
Proc. Acad. Nat. Sci., Phila., vol. xx, pp. 184-194, 1869.
Some whale vertebræ from the Miocene of the Nomini Cliffs are described.

MAURY, M. F. Physical Survey of Virginia, vol. i, 90 pp., 1868; vol. ii, 142 pp., 1878, Richmond.
Contains references to the geological formations of the state.

1869

CONRAD, T. A. Descriptions of and References to Miocene Shells of the Atlantic Slope, and Descriptions of Two New Supposed Cretaceous Species.
Amer. Jour. Conch., vol. iv, pp. 278-279, pls. 19, 20, 1869.
Callista densata from Petersburg and *Caryatis plionema* are described and figured.

——— Descriptions of Miocene, Eocene and Cretaceous shells.
Amer. Jour. Conch., vol. v, pp. 39-45, pls. 1, 2, 1869.
Callista virginiana from the Miocene of Petersburg is described and figured.

COPE, E. D. Third Contribution to the Fauna of the Miocene Period of the United States.
Proc. Acad. Nat. Sci., Phila., vol. xxi, pp. 6-12, 1869.
A whale and a crocodile are described from fragments of the skeletons found in the Miocene strata of Virginia.

LEIDY, JOSEPH. Synopsis of Extinct Mammalia of North America.
Jour. Acad. Nat. Sci., Phila., (n. s.), vol. vii, pp. 363-472 with pls., 1869.

Cetacean remains from the Miocene of Westmoreland County, Richmond and City Point are described and figured. The statement is made that remains of walrus have been found in the superficial deposits of Accomac County.

1871

COPE, E. D. Synopsis of the Extinct Batrachia, Reptilia, and Aves of North America.

Trans. Amer. Philos. Soc., vol. xiv, pp. 1-252.

Mention is made of the beak of an Eocene fish *Cœlorhynchus ornatus* Leidy found near Petersburg, and a crocodile from "Eocene" of Eastern Virginia.

1872

SHALER, N. S. On the Causes which have led to the Production of Cape Hatteras.

Proc. Boston Soc. Nat. Hist., vol. xiv, pp. 110-123, 1872.

Abstr. Amer. Nat., vol. v, pp. 178-181, 1871.

The author believes that Delaware and Chesapeake bays were excavated by streams of ice which poured down the valleys of the Delaware and Susquehanna rivers during the Ice Age and the resulting debris was dropped farther south, forming Cape Hatteras and the eastern part of Virginia. The difference in topography south of the James River is supposed to be due to a recent subsidence of that region which was contemporaneous with the uplift of the northern part of the country on the melting of the ice sheet.

1873

HOTCHKISS, JED. On the Virginias; their Agricultural, Mineral, and Commercial Resources.

Soc. Arts (London) Jour., vol. xxi, pp. 238-251, 1873.

The article contains a brief description of the "Tide-water Country."

1875

WEBSTER, N. B. On the Physical and Geological Characteristics of the Great Dismal Swamp and the Eastern Counties of Virginia.

Amer. Nat., vol. ix, pp. 260-262, 1875.

The writer supposes that the basin of Lake Drummond was formed by the burning of the peat at some time in the past and the depression resulting was later filled with water. "The perpendicular banks of the lake and the charred stumps that have been found at the bottom confirm this supposition."

1876

CORYELL, MARTIN. Diatomaceous Sands of Richmond, Va.

Trans. Amer. Inst. Min. Eng., vol. iv, pp. 230-232, pl., 1876.

The Virginias, vol. ii, pp. 6-7.

The brief article is accompanied by a profile showing the geological structure of Church Hill between Shockoe and Gillies creeks.

HOTCHKISS, JED. Virginia: A geological and political summary, embracing a description of the State, its geology, soils, minerals, climate, etc., 319 pp., 4 maps.

Richmond, 1876. Not seen.

1877

ROGERS, WM. B. On the Gravel and Cobble-Stone Deposits of Virginia and the Middle States.

Proc. Boston Soc. Nat. Hist., vol. xviii, pp. 101-106, 1877.

Reprint of Reports on the Geology of the Virginias, pp. 709-713, New York, 1884. Abstr. Amer. Jour. Sci., 3d ser., vol. ii, pp. 60-61, 1876.

The lithological characteristics of the superficial deposits (Pleistocene) are described, and also their stratigraphic relation to the underlying strata. The author supposes that there is some close connection between the gravels and the glacial drifts of the northern states; either the materials represent transported and water-deposited glacial drift or merely the coarse river sediments brought down by the flooded rivers during the glacial period. The resemblance of the superficial deposits and those beds referred to the Upper Secondary (Potomac) is noted. The latter are considered to be Jurassic in age.

STODDER, CHARLES. A Contribution to Microgeology. Read Dec. 8, 1875.

Proc. Boston Soc. Nat. Hist., vol. xviii, pp. 206-209, 1877.

Abstr. Amer. Jour. Sci., 3d ser., vol. ii, pp. 493, 494, 1876.

The writer gives a list of 50 species of diatoms and 6 species of rhizopods found in the diatomaceous earth at Richmond. He reports that the upper strata lack many forms found in the lower layers.

1879

FONTAINE, WILLIAM M. Notes on the Mesozoic Strata of Virginia.

Amer. Jour. Sci., 3d ser., vol. xvii, pp. 25-39, 151-157, 229-239, 1879. Abstr. Neues Jahrbuch, pp. 137-138, 1881.

The Potomac deposits and their fossils are described briefly and the suggestion is made that perhaps the deposits were found during a Mesozoic ice age. The author quotes Lyell as noting the resemblance between these deposits and the northern Glacial Drift.

HEINRICH, OSWALD J. The Mesozoic Formation in Virginia.

Trans. Amer. Inst. Min. Eng., vol. vi, pp. 227-274, pl. 1879.

The Virginias, vol. i, pp. 120-126, 142-145, 155, 176-177, 190-192, pl.

The limits of the Mesozoic formations including the Potomac deposits are given and their characteristics discussed briefly.

MACFARLANE, JAMES. An American Geological Railway Guide.

219 pp., New York, 1879; 2d edit., revised and enlarged, 426 pp. New York, 1890.

Contains many brief statements concerning the Coastal Plain region of Virginia.

POLLARD, THOMAS. A Handbook, 144 pp., Richmond, 1879.

Bound in 22d. Ann. Rept. of Commissioner of Agriculture of the State of Virginia, Richmond, 1879.

Not seen.

1880

MICHELS, JOHN. The Richmond Diatomaceous Earth.

Science, vol. i, pp. 222, 1880.

The writer describes the occurrence of the diatomaceous earth and its general characteristics. It is said to consist of 10 per cent. unbroken forms of diatoms, 25 per cent. white sand, and the balance white clay.

1882

FONTAINE, WILLIAM M. The Artesian Well at Fort Monroe, Va.

The Virginias, vol. iii, pp. 18, 19, 1882.

The combined Eocene and Miocene strata in this well have a thickness of at least 800 feet. At a depth of 851 feet the boring was doubtless in Mesozoic strata, and at 885 feet the plant-bearing clay exposed at Dutch Gap was encountered.

ROGERS, WM. B. The Infusorial Deposits of Virginia in the Fort Monroe Artesian Well.

The Virginias, vol, iii, pp. 151, 152, 1882. Reprint of Reports on the Geology of the Virginias, pp. 731-736, New York, 1884.

Of 40 species of diatoms from the infusorial stratum reached at a depth of 558 feet, Mr. Samuel Wells reports that 29 are identical with species found at Richmond, thus seeming to prove that they come from the same stratum. The presence of Cretaceous strata between the Eocene and Jurasso-Cretaceous strata is also revealed in the same well section.

1883

HEILPRIN, A. On the Relative Ages and Classification of the Post-Eocene Tertiary Deposits of the Atlantic Slope.

Proc. Acad. Nat. Sci., Phila., vol. xxxiv, pp. 150-186, 1883.

Abstr. Amer. Nat., vol. xvii, pp. 308, 309, 1883; Amer. Jour. Sci., 3d ser., vol. xxiv, pp. 228, 229, 1882.

From a comparison of the fossils from the Miocene of Maryland, Virginia, and North and South Carolina, the author concludes that the Miocene should be divided into three formations—the Marylandian, including the oldest of the Maryland and Virginia Miocene strata, the Virginian, including the upper strata in those states, and the Carolinian, including the deposits of the Carolinas.

1884

HEILPRIN, A. Contributions to the Tertiary Geology and Paleontology of the United States.

117 pp., map. 4°, Phila., 1884.

The portions referring to Virginia are reprints of previous published articles mentioned above. On the map which accompanies the report a large area is shown as Carolinian, the upper division of the Atlantic Coast Miocene.

——— The Tertiary Geology of the Eastern and Southern United States.

Jour. Acad. Nat. Sci., Phila., vol. ix, pp. 115-154, map, 1884.

The geographical distribution of the Eocene and Miocene deposits are given. The Eocene deposits are referred to the Eo-Lignitic and Buhrstone formations of the southern states, while the Miocene deposits are grouped in the divisions of Marylandian and Virginian. The author thinks that possibly the Miocene deposits about Yorktown and Suffolk represent a later division which he has called Carolinian because of its development in the Carolinas.

Rogers, Wm. B. A Reprint of Annual Reports and other Papers on the Geology of the Virginias.

xv+832 pp., pls., maps, New York, 1884.

The various articles contained in this volume in which references are made to the Coastal Plain province have been given on preceding pages.

1885

Harrison, Randolph. Handbook of Virginia.

4th edit., 182 pp., map, pl., Richmond, 1885.

6th edit., 1886.

Not seen.

1888

Heilprin, A. The Classification of the Post-Cretaceous Deposits.

Proc. Acad. Nat. Sci., Phila., pp. 314-322, 1888.

The Eocene is divided into the Eo-Lignitic, Buhrstone, Clabornian, and Jacksonian and the Miocene into the Marylandian, Virginian, and Carolinian.

McGee, W J The Columbia Formation.

Proc. Amer. Assoc. Adv. Sci., vol. xxxvi, pp. 221-222, 1888.

The author divides the Pleistocene into two classes, the delta deposits laid down along the inland margin of the Coastal Plain by the Middle Atlantic slope rivers during a period of submergence ranging from 100 to 450 feet, and the terraced littoral deposits connecting and graduating into the deltas and covering the remainder of the Coastal Plain to the Atlantic Ocean. A bipartition of the deposits is frequently apparent and these two divisions are supposed to be contemporaneous with two ice-sheets which covered the northern portion of the country during Pleistocene time.

——— Three Formations of the Middle Atlantic Slope.

Amer. Jour. Sci., 3d ser., vol. xxxv, pp. 120-143, 328-330, 367-388, 448-466, pls. 2, 6-7; Abstr. Nature, vol. xxxviii, pp. 91, 190; Amer. Geol., vol. ii, pp. 129-131, 1888.

The three formations which are described in considerable detail are, (1) the Potomac (now divided into four formations); (2) the Appomattox (now called the Lafayette); and (3) the Columbia (now divided into three formations). The views expressed in this paper are but slightly at variance with those held by the authors of this report.

WARD, L. F. Evidence of the Fossil Plants as to the Age of the Potomac Formation.

Amer. Jour. Sci., 3d ser., vol. xxxvi, pp. 119-131, 1888. Abstr. Nature, vol. xxxviii, p. 462, 1888.

The author concludes in regard to the Potomac formation that "if the stratigraphical relations and the animal remains shall finally require its reference to the Jurassic, the plants do not present any serious obstacle to such reference."

1889

CURTICE, COOPER. Oriskany Drift near Washington, D. C.

Amer. Geol., vol. iii, pp. 223-225, 1889.

The writer states that he found water-worn pebbles and cobbles near Alexandria and Mt. Vernon carrying fossils of Oriskany age. Nine genera and eight species have been determined. The writer states that the cobbles come from the Potomac but it is not improbable that they came from the Columbia deposits. They were transported from the region beyond the Blue Ridge.

FONTAINE, WILLIAM M. The Potomac or younger Mesozoic Flora.

U. S. Geol. Survey, Monograph, vol. xv, pt. i, 377 pp.; pt. ii, 180 pls., Washington, 1889.

The monograph contains a description of the Potomac deposits of Virginia in which the lithologic characters of the deposits and their geographic occurrence are discussed in considerable detail. Three hundred and sixty-five species of fossil plants, most of them new, are described and figured.

KNOWLTON, F. H. Fossil Wood and Lignite of the Potomac Formation.

Bull. U. S. Geol. Survey, No. 56, 72 pp., 7 pls., Washington, 1889.

The author described the organic remains of the Potomac and their method of occurrence and gives a detailed description of the microscopic appearance of five new species of silicified wood, four of which were obtained from the Potomac strata of Virginia.

——— The Fossil Wood and Lignites of the Potomac Formation.

Amer. Geol., vol. iii, pp. 99-106, 1889.

After a careful microscopic examination of the silicified wood and lignite the author concludes that all belong to the conifers. The cells of the lignite have been so much distorted and metamorphosed that the specific determinations could not be made. The silicified specimens are very perfectly preserved and belong to two genera *Cupressinoxylon* with four species and *Araucarioxylon* with a single species.

1890

CLARK, WILLIAM B. Third Annual Geological Expedition into Southern Maryland and Virginia.

Johns Hopkins Univ. Circulars, vol. x, No. 81, pp. 69-71.

On the trip various localities along the Potomac, York, and James rivers were visited for the study of the Cretaceous, Tertiary, and Quaternary formations of the Coastal Plain. Sections of the strata at Aquia Creek, Nomini Cliffs, Yorktown, and Grove Wharf are given.

Cope, E. D. The Cetacea.

Amer. Nat., vol. xxiv, pp. 599-616, pls. 20-23.

In a list of extinct Cetacea of North America some forms from the Miocene of Virginia are named.

Shaler, Nathaniel S. General Account of the Fresh-water Morasses of the United States, with a Description of the Dismal Swamp District of Virginia and North Carolina.

U. S. Geol. Survey, 10th Ann. Rept., pp. 255-339, pls. 6-19, Washington, 1890. Abstr., pp. 15-16.

The geology, topography, and general character of the vegetation of the Dismal Swamp are discussed in considerable detail. A list of 29 species of shells obtained from the vicinity of the Jericho Canal are given of which 24 belong to living and 5 to extinct species. The conclusion is reached that the fossiliferous beds beneath the swamp are Pliocene in age.

1891

Darton, N. H. Mesozoic and Cenozoic Formations of Eastern Virginia and Maryland.

Bull. Geol. Soc. Amer., vol. ii, pp. 431-450, pl. 16, 1891.

The geographical distribution, characteristics and stratigraphic relations of the Pamunkey (Eocene), Chesapeake (Miocene), and Appomattox (Lafayette) formations in Maryland and Virginia are discussed.

Lindenkohl, A. Notes on the Submarine Channel of the Hudson River and other Evidences of Post-Glacial Subsidence of the Middle Atlantic Coast Region.

Amer. Jour. Sci., 3d ser., vol. xli, pp. 489-499, 18 pls. 1891.

The author describes the submerged channel of Chesapeake Bay.

1891

McGee, W J With the Collaboration of G. H. Williams, N. H. Darton and B. Willis.

The Geology of Washington and vicinity. Guide to Washington, prepared for the International Cong. Geol., 5th session. Washington, 1891.

Contains a general description of the physiography and the geological formations of the Coastal Plain.

——— The Lafayette Formation.

U. S. Geol. Survey, 12th Ann. Rept., pp. 347-521, 1891.

The article embraces a general description of the physiography and geology of the Coastal Plain and a detailed description of the lithologic characteristics of the Lafayette formation, together with its geographical distribution, its economic importance, and the geologic history recorded in the formation.

WHITE, CHARLES A. Correlation Papers—Cretaceous.

U. S. Geol. Survey, Bull. No. 82, 273 pp., 3 pls., Washington, 1891.

This bulletin contains a brief résumé of the previously published articles on the Potomac deposits of Virginia.

WOOLMAN, LEWIS. Note on the Extension Southward of Diatomaceous Clays and the Occurrence there of Flowing Wells.

Geol. Surv. of New Jersey, Report for 1890, pp. 275-276, 1891.

The author mentions many localities in Virginia where diatomaceous earth outcrops and other places where it has been reached in well borings.

1892

CLARK, W. B. Correlation Papers—Eocene.

U. S. Geol. Survey, Bull. No. 83, 159 pp., 2 pls., 1892; Abstrs. Amer. Geol., vol. xii, p. 379, 1893; Amer. Nat., vol. xxvi, pp. 330-332, 1892.

The paper embodies an historical review of the literature and a general summary of all existing knowledge concerning the Eocene strata of the United States. The Virginia deposits are briefly described.

DALL, W. H. AND HARRIS, G. D. Correlation Papers. Neocene.

U. S. Geol. Survey, Bull. No. 84, 349 pp., 3 pls., 43 figs., 1892.

Contains a general summary of all existing information concerning the Miocene and Pliocene deposits of Virginia based principally upon the work of Rogers and Conrad.

1893

CLARK, W. B. The Eocene of the United States.

Johns Hopkins Univ. Circ., vol. xii, pp. 50, 51, 1893.

Contains a brief synopsis of the Eocene Correlation bulletin No. 83 of the United States Geological Survey.

1894

DARTON, N. H. Fredericksburg Folio, Virginia-Maryland.

U. S. Geol. Survey, Geol. Atlas of U. S., Folio No. 13, 1894.

The topography, geology, and economic resources of the Fredericksburg quadrangle, which includes all of King George County and considerable portions of Stafford, Spottsylvania, Caroline, Essex, and Westmoreland counties, are discussed in the text and represented on the accompanying maps drawn to the scale of 1:125,000.

——— On Fossils in the Lafayette Formation in Virginia.

Amer. Geol., vol. ix, pp. 181-183, 1892.

The Lafayette is reported to extend down the peninsula from the Piedmont Plateau almost to Chesapeake Bay. Water-worn shells are reported from the Lafayette deposits near Heathsville, Northumberland County, but it is possible, if not probable, that they were derived from the Miocene. The fossils were too poorly preserved to be definitely determined.

——— Outline of Cenozoic History of a Portion of the Middle Atlantic Slope.

Jour. Geol., vol. ii, pp. 568-587, 1894.

The Cenozoic history of the Middle Atlantic Coastal Plain is described and the development of the present topography discussed. A small scale map shows the distribution of the Columbia deposits in Virginia.

HARRIS, GILBERT D. On the Geological Position of the Eocene Deposits of Maryland and Virginia.

Amer. Jour. Sci., 3d ser., vol. xlvii, pp. 301-304, figs. 1-3, 1894.

On the basis of the fossils the Eocene strata of Maryland and Virginia are correlated with the Lignitic stage of the southern states.

1895

BAGG, R. M. Protozoa (Eocene Fauna of the Middle Atlantic Slope).

Johns Hopkins Univ. Circ., vol. xv, p. 6, 1895.

A list of 21 species of foraminifera from Woodstock and the Pamunkey River is given of which one is a new species and is described.

CLARK, W. B. Contributions to the Eocene Fauna of the Middle Atlantic Slope.

Johns Hopkins Univ. Circ., vol. xv, pp. 3-6, 1895.

From a study of the Eocene fauna of Maryland and Virginia the author divides the Eocene strata of these states into two stages, the Aquia Creek and Woodstock. He believes that they represent the Lignitic, Buhrstone, Claiborne, and possibly part of the White Limestone of the Alabama region.

——— Descriptions of the Geological Excursions made during the Spring of 1895.

Johns Hopkins Circ., vol. xv, pp. 1-3, 1895.

The outcrops of the Potomac Eocene and Miocene strata along the Potomac River are briefly described.

1895

COPE, E. D. Fourth Contribution to the Marine Fauna of the Miocene Period of the United States.

Proc. Amer. Philos. Soc., vol. xxiv, pp. 135-155, pl. 6.

Cetotherium megalophysum, a new species from the Miocene at Tar Bay on the James River is described.

DARTON, N. H. Artesian Well Prospects in Eastern Virginia, Maryland and Delaware.

Amer. Inst. Min. Engrs. Trans., vol. xxiv, pp. 372-397, pls. 1-2, 1895.

The geological occurrence of artesian water in the Coastal Plain is discussed and the records of many deep wells, especially those in the vicinity of Norfolk, are given.

Gane, Henry Stewart. A Contribution to the Neocene Corals of the United States.

Johns Hopkins Univ. Circ., vol. xv, pp. 8-10. 1895.

The author believes "that the corals of the Neocene flourished as shallow-water forms with preponderating reef-building tendencies." Five species from the Miocene of Virginia are described, one of which is new.

Vaughan, T. Wayland. Coelenterata (Eocene Fauna of the Middle Atlantic Slope).

Johns Hopkins Univ. Circ., vol. xv, p. 6, 1895.

Describes two new species of corals from the Eocene deposits at Aquia and Potomac creeks, Virginia.

1896

Bagg, R. M. (Protozoa from the Eocene Deposits of Delaware, Maryland, and Virginia.)

U. S. Geol. Survey, Bull. No. 141, pp. 91, 92. 1896.

A list of 21 species of foraminifera from the Eocene deposits of Virginia is given, 16 from Woodstock and 5 from the Pamunkey River.

Clark, W. B. The Eocene Deposits of the Middle Atlantic Slope in Delaware, Maryland, and Virginia.

U. S. Geol. Surv., Bull. No. 141, 167 pp., 40 pls., 1896. Review by C. R. Keyes, Jour. Geol., vol. v, pp. 310-312, 1897.

The paper contains a bibliography and historical review of the literature of the Eocene of the Middle Atlantic region and a discussion of the stratigraphy and paleontological characteristics of the deposits. Two distinct faunas, the Aquia Creek and Woodstock are recognized. The most important fossils are described and figured.

——— The Potomac River Section of the Middle Atlantic Coast Eocene.

Amer. Jour. Sci., 4th ser., vol. i, pp. 365-374, 1896.

The lithology and paleontology of the Eocene strata of the Potomac River basin are described. The author believes they represent a single geological unit, the Pamunkey formation with two clearly defined faunal zones, the Aquia Creek stage and the Woodstock stage.

Cope, E. D. Sixth Contribution to the Knowledge of the Marine Miocene Fauna of North America.

Proc. Amer. Philos. Soc., vol. xxxv, pp. 139-146, pls. 11, 12.

Syllomus crispatus gen. and sp. new from the Miocene along the Pamunkey River. *Rhegnopsis palæatlanticus* Leidy from the Miocene of Southeastern Virginia, and *Cetotherium leptocentrum* Cope from the James River are described and figured.

Darton, N. H. Artesian Well Prospects in the Atlantic Coastal Plain Region.

U. S. Geol. Survey, Bull. No. 138, 228 pp., 19 pls., 1896.

Contains much information concerning the deep wells and the water-bearing strata of the Coastal Plain of Virginia.

——— Nomini Folio, Maryland-Virginia.
U. S. Geol. Survey, Geol. Atlas of U. S., Folio No. 23, 1896.
The topography, geology, and economic resources of the Nomini quadrangle which embraces a considerable portion of Westmoreland, Richmond, and Essex counties are discussed in the text and represented on maps drawn to the scale of 1 :125,000.

FONTAINE, WILLIAM M. The Potomac Formation in Virginia.
U. S. Geol. Survey, Bull. No. 145, 149 pp., 2 pls., 1896.
The author describes in considerable detail all the principal exposures of the Potomac deposits in Virginia.

VAUGHAN, T. WAYLAND. Coelenterata from the Eocene Deposits of Delaware, Maryland, and Virginia.
U. S. Geol. Survey, Bull. No. 141, pp. 89-91, 1896.
The description of three species of corals from Aquia Creek and one from the Pamunkey River in New Kent County are given.

1897

ALDRICH, T. H. Notes on Eocene Mollusca, with Descriptions of new species.
Bull. Amer. Pal., vol. ii, No. 8, 26 pp., 5 pls., Ithaca, 1897.
Crassatella declivis Heilprin from Aquia Creek and *Ringicula dalli* Clark from Woodstock are figured.

CLARK, W. B. Outline of Present Knowledge of the Physical Features of Maryland, Embracing an Account of the Physiography, Geology, and Mineral Resources.
Md. Geol. Survey, vol. i, pp. 141-228, pls. 6-13, 1897.
Contains many references to the Coastal Plain deposits of Virginia.

CLARK, W. B. AND BIBBINS, A. The Stratigraphy of the Potomac Group in Maryland.
Jour. Geol., vol. v, pp. 479-506, 1897.
A new classification of the Potomac deposits is proposed by which they are divided into the Patuxent, Arundel, Patapsco, and Raritan formations on stratigraphic grounds. The first two are doubtfully referred to the Jurassic, the last two to the Cretaceous.

WATSON, THOMAS L. A Bibliography of the Geological, Mineralogical and Paleontological Literature of the State of Virginia.
Bull. Amer. Pal., vol. ii, No. 7, 109 pp., 1897.
Gives a list of journals consulted and a bibliography arranged alphabetically by names of authors.

1898

BAGG, R. M. The Tertiary and Pleistocene Foraminifera of the Middle Atlantic Slope.
Bull. Amer. Pal., vol. ii, No. 10, 68 pp., 3 pls., 1898.
Fifty-six species of Eocene, Miocene, and Pleistocene foraminifera are described and figured, of which many were obtained from the Virginia deposits.

DALL, W. H. A Table of North American Tertiary Horizons correlated with one another and with those of Western Europe, with Annotations.

U. S. Geol. Survey, 18th Ann. Rept., pt. ii, pp. 327-348, 1898.

The Eocene beds of Virginia are placed in the Chickasawan stage near the base of the Eocene and correlated with the Suessonian of Europe and the Miocene deposits are correlated with the Helvetian beds of Europe.

DARTON, N. H. Discovery of Marine Cretaceous in Boring at Norfolk, Virginia.

Abstr. Geol. Soc. Amer. Bull., vol. ix, pp. 414-416.

The presence of marine Cretaceous shells is reported in a deep well at Norfolk between the depths of 715 and 775 feet and at Lamberts Point between 563 and 616 feet.

1899

GLENN, L. C. The Hatteras Axis in Triassic and Miocene Time.

Amer. Geol., vol. xxiii. pp. 375-379, 1899.

The view is expressed that the region in the vicinity of Cape Hatteras was not submerged during early Miocene time and this accounts for the discontinuity of the lower Miocene deposits of Virginia with those of the Carolinas.

WOOLMAN, LEWIS. Artesian Wells.

Ann. Rept. N. J. Geol. Survey for 1898, pp. 121-126, 1899.

Records of two artesian wells in the Coastal Plain of Virginia are given, one at Fairport in Northumberland County, and the other at Old Point Comfort. Marine Cretaceous fossils were found at depth of 640 feet at Fairport and at depth of 840 feet at Old Point Comfort. A list of Miocene forms from latter well is also given.

——— Fossil Mollusks and Diatoms from the Dismal Swamp, Virginia and North Carolina: Indication of the Geologic Age of the Deposits: with Notes on the Diatoms by Charles C. Boyer.

Proc. Acad. Nat. Sci., 1898, pp. 414-429, 1899.

Forty-nine species of mollusca were obtained form the Dismal Swamp near Wallaceton and Suffolk. Of these 7 species are Pliocene and pre-Pliocene forms, 16 species range from Miocene to Recent; 14 species are found in both Pliocene and Recent deposits; and 12 species are Pleistocene or Recent. From these facts the author concludes that the fossiliferous deposits underlying the Dismal Swamp are not older than late Pliocene and may be Pleistocene in age.

1900

BOYER, C. S. The Biddulphoid Forms of North American Diatomacea.

Proc. Acad. Nat. Sci., Phila., pp. 685-748, 1900.

Describes many forms occurring in the Miocene deposits of Virginia.

GANE, HENRY STEWART. Some Neocene Corals of the United States.

Proc. U. S. Nat. Mus., vol. xxii, pp. 179-198, pl. 15.

Some Miocene species from Virginia are described, one of which is also figured

GANNETT, HENRY. Physiographic Types.
U. S. Geol. Survey Topog. Atlas of U. S., Folio No. 2, 1900.
The Norfolk topographic sheet is included in the folio to illustrate a coast swamp.

VAUGHAN, T. WAYLAND. The Eocene and Lower Oligocene Coral Faunas of the United States.
U. S. Geol. Survey, Monogr. xxxix, 263 pp., 24 pls., 1900.
Several species of corals from the Eocene deposits of Virginia are described and figured.

1901

CLARK, W. B. and others. Maryland Geological Survey. Eocene.
331 pp., 64 pls., Baltimore, 1901.
The Eocene deposits on the Potomac River in Virginia are discussed and many fossils from that region are described and figured.

DARTON, N. H. and KEITH, ARTHUR. Washington Folio, Dist. of Columbia, Maryland, Virginia.
U. S. Geol. Survey, Geol. Atlas of U. S., Folio No. 70, 1901.
The topography, geology, and economic resources of the Washington quadrangle, which includes a considerable area in Virginia are discussed in the text of the folio and represented on the accompanying maps drawn to the scale of 1:62,500.

1902

DARTON, N. H. Norfolk Folio, Virginia-North Carolina.
U. S. Geol. Survey, Geol. Atlas of U. S., Folio No. 80, 1902.
The topography, geological formations, and economic resources of the Norfolk region are discussed and represented on accompanying maps drawn to the scale of 1:125,000. A good description is given of the Dismal Swamp.

1903

RIES, HEINRICH. The Clays of the United States east of the Mississippi River.
U. S. Geol. Survey, Professional Paper No. 11, 298 pp., 9 pls., 11 figs., 1903.
Gives a very brief account of the geologic and geographic distribution of the clay deposits in the Coastal Plain of Virginia.

1904

CLARK, W. B. and others. Maryland Geological Survey. Miocene.
cxxxvii+543 pp., 135 pls., Baltimore, 1904.
Many references are made to the Miocene deposits of Virginia while the Virginia fossils are frequently mentioned. Most of the forms described from the Maryland deposits also occur in Virginia.

1905

WARD, LESTER F. with the collaboration of FONTAINE, W. M., BIBBINS, A., and WIELAND, G. R.

Status of the Mesozoic Floras of the United States. Mono. U. S. Geol. Survey. vol. xlviii, 616 pp., 119 pls., 11 figs.

The various plant-bearing beds of the Potomac deposits in Virginia are described and lists given of the plants occurring at each place. Most of the species named are described and figured. In a columnar section the Potomac deposits in Virginia are given a thickness of 525 feet, of which the lower 350 feet are designated as the James River and Rappahannock beds, and correlated with the Arundel and Patuxent formations; above are the Mount Vernon beds with a thickness of 25 feet and correlated with the base of the Patapsco formation; and at the top are the Brook beds, 150 feet in thickness, which are correlated with the upper part of the Patapsco formation. The author believes all of the Potomac strata are Cretaceous in age.

1906

BERRY, EDWARD W. Pleistocene Plants from Virginia.

Torreya, vol. vi, pp. 88-90, 1906.

Contains brief description of the fruit of the hickory, grape, beech, cypress, and black gum found in the Pleistocene swamp deposits near Tappahannock on the Rappahannock River.

BERRY, EDWARD W. and GREGORY, WILLIAM K. Prorosmarus alleni, a New Genus and Species of Walrus from the Upper Miocene of Yorktown. Virginia.

Amer. Jour. Sci., 4th ser., vol. xxi, pp. 444-450, figs. 1-4, 1906.

Contains a description of half of a lower jaw of a walrus found on the beach at Yorktown washed from the fossiliferous Miocene beds that form the cliffs at that point.

CLARK, WM. BULLOCK and MATHEWS, EDWARD B. Report on the Physical Features of Maryland.

Md. Geol. Surv., vol. vi, pt. 1, 1906, pp. 27-251, pls. 2-23.

Frequent references are made to Virginia and the relations of the entire Coastal Plain of which Virginia is a part.

RIES, HEINRICH. The Clay Deposits of the Virginia Coastal Plain with a chapter on the Geology of the Virginia Coastal Plain by William Bullock Clark and Benjamin LeRoy Miller.

Geol. Survey of Virginia, Geol. ser., Bull. No. 2, 184 pp., 15 pls., 10 figs., 1906

Contains a detailed account of the localities in the Virginia Coastal Plain where the clay deposits are now being utilized and a brief sketch of the geology of the region.

SHATTUCK, G. B. Md. Geol. Survey. Pliocene and Pleistocene. 291 pp., 75 pls., Baltimore, 1906.

Many references are made to the Pliocene and Pleistocene deposits of Virginia. Most of the species described from the Maryland deposits also occur in Virginia.

1907

CLARK, WM. BULLOCK. The Classification adopted by the U. S. Geological Survey for the Cretaceous Deposits of New Jersey, Delaware, Maryland and Virginia.

Johns Hopkins University Circulars, new ser., 1907, No. 7, pp. 1-4 (589-592), Baltimore, 1907.

Contains a brief discussion of the Cretaceous formational names of the Northern Atlantic Coastal Plain.

WATSON, THOMAS L. Mineral Resources of Virginia. Virginia-Jamestown Exposition Commission, 1907.

xxxi+619 pp., 83 pls., 101 figs.

Describes the general geology and mineral resources of Virginia, including the Coastal Plain region.

1909

BERRY, EDWARD W. A Miocene Flora from the Virginia Coastal Plain.

Jour. Geol., vol. xvii, pp. 19-30, 11 figs., 1909.

Fourteen species of fossil plants, six of which are new ones, from the diatomaceous earth at Richmond are described. The writer states that the flora indicated the formation of the deposits near the shore of a marine body of water.

BERRY, EDWARD W. Pleistocene Swamp Deposits of Virginia.

Amer. Nat., 1909, vol. xliii, pp. 432-436, figs. 1, 2.

SMITH, BURNETT. Note on the Miocene Drum Fish *Pogonias multidentatus* Cope.

Amer. Jour. Sci., 4th ser., vol. xxviii, pp. 275-282, figs. 1-13, 1909.

Contains description and figures of this rare species which was originally described by Cope in 1869.

WATSON, THOMAS L. Annual Report on the Mineral Production of Virginia During the Calendar Year 1908.

Bulletin No. I-A Virginia Geological Survey, 141 pp., map and 25 figs, 1909.

1910

BERRY, EDWARD W. A Revision of the Fossil Plants of the genera Acrostichopteris, Tæniopteris, Nilsonia, and Sapindopsis from the Potomac Group.

Proc. U. S. Natl. Mus., vol. xxxviii, 1910, pp. 625-644.

———. A Revision of the Fossil Plants of the genus Nageiopsis of Fontaine.

Proc. U. S. Natl. Mus., vol. xxxviii, 1910, pp. 185-195, tf. 1, 2.

———. The epidermal characters of Frenelopsis ramosissima.
Bot. Gazette, vol. 1, 1910, pp. 305-309, tf. 1, 2.

———. Geologic relations of the Cretaceous Floras of Virginia and North Carolina.
Bull. Geol. Soc. Amer., vol. xx, 1908, pp. 655-659.
Abstr. Science, N. S. vol. xxix, p. 629, 1909.

CLARK, WM. BULLOCK. Results of a recent investigation of the coastal plain formations in the area between Massachusetts and North Carolina.
Bull. Geol. Soc. Amer., vol. xx, 1910, pp. 646-654.
Abstr. Science, N. S. vol. xxix, p. 629, 1909.

MILLER, BENJAMIN L. Erosion Intervals in the Tertiary of North Carolina and Virginia.
Bull. Geol. Soc. Amer., vol. xx, pp. 673-678.

1911

BERRY, EDWARD W. A Lower Cretaceous species of Schizæaceæ from eastern North America.
Annals of Botany, vol. xxv, 1911, pp. 193-198, tf. 1, pl. xii.

———. A revision of several genera of gymnospermous plants from the Potomac Group in Maryland and Virginia.
Proc. U. S. Natl. Mus., vol. xl, 1911, pp. 289-318.

———. A revision of the fossil ferns from the Potomac Group which have been referred to the genera Cladophlebis and Thyrsopteris.
Proc. U. S. Natl. Mus., vol. xli, 1911, pp. 307-332.

Besides the above named articles there are many brief references to the economic resources of the Virginia Coastal Plain in the statistical publications of the U. S. Geological Survey and in the special reports of the U. S. Census Office.

PHYSIOGRAPHY OF THE VIRGINIA COASTAL PLAIN

INTRODUCTORY.

As has been previously stated, the Coastal Plain falls naturally into two divisions, a submerged or submarine portion and an emerged or subaerial portion, the shore-line of the Atlantic Ocean forming the boundary between them. This line of demarcation, although apparently fixed, is in reality very changeable, for during the past geologic ages it has migrated back and forth across the Coastal Plain, at one time occupying a position well over on the Piedmont Plateau and at another far out to sea. At the present time there is reason to believe that the shore-line is encroaching on the land by a slow subsidence of the latter, but a few generations of men afford a scarcely long enough period in which to determine this point definitely.

SUBMARINE DIVISION.

GENERAL CHARACTERISTICS.

The submerged portion of the Coastal Plain may be described as a broad plain with a very even surface sloping gently seaward beneath sea level. In the vicinity of the edge of the continental shelf these characters are very noticeable, but as the land is approached the surface becomes decidedly undulating. Small hills, which appear as shoals, increase in number and in size as the water becomes shallower until they finally rise above the water's level. The slopes of these shoals are gentle and they are usually elliptical in shape with the long diameter parallel to the shore-line. If contour lines at intervals of one fathom should be drawn on the charts of the United States Coast and Geodetic Survey along the eastern shores of Virginia, they would be found to be roughly parallel to the shore-line, but there would be frequent irregularities and many closed contours marking the small submerged hillocks. Except near inlets where the tidal currents maintain a deeper channel in the center and have produced numerous hooks and spits, the one-fathom contour is a fairly constant line distant from the shore on an average of from one-eighth to one-quarter of a mile. The two-fathom line is about the same distance farther east while the succeeding lines for a distance of several miles are considerably farther apart and only again come nearer together as the edge of the continental shelf is approached.

The material covering the submarine Coastal Plain near the shore is primarily fine sand mixed with numerous broken shells, which furnish

evidence of the abundance of molluscan forms inhabiting the region, while here and there occur local deposits of pebbles and also of blue mud. Seaward the deposits become finer until in the vicinity of the continental slope muddy deposits predominate.

OFF-SHORE BEACHES AND BARS.

As the large waves from the deeper parts of the Atlantic Ocean advance toward the land they finally reach a place where the lower part of the wave drags on the bottom. The unconsolidated material is carried landward until the wave finally breaks. The smaller wave current then continues to carry part of the fine sand forward. Some is carried back by the undertow current, while some is left heaped up in a ridge formed parallel to the advancing wave front. Thus in time a chain of sand-bars which may become considerable islands is formed a short distance from the former shore-line and with each succeeding storm these are either enlarged or cut away. As these increase in size sand dunes form upon them and thus the elevation above the sea may become so great that the largest storm waves never sweep over them. Bordering the eastern shore of the State is a chain of long, narrow, low-lying sandy islands formed in this way, and separated from each other by narrow inlets through which the tide enters and leaves the lagoons formed back of the islands. Many of these islands are very narrow and scarcely rise above the water, but others are a mile or more in width and are inhabited by considerable colonies of fishermen. The most important of these islands are Chincoteague, Assateague, Metomkin, Paramores Beach, Hog, Cobbs, and Smith on which is located the Cape Charles light house.

COASTAL LAGOONS.

Between the sandy beaches just described and the shore is a series of shallow-water lagoons of variable width from one-half mile to six or eight miles. Bordering these on either side is usually a considerable belt of salt to fresh water marshes. The average depth of water is only three or four feet, except in the channels through which the tide enters and leaves. The amount of water flowing through the narrow inlets between the islands is so great that occasionally very strong tidal currents are produced, currents strong enough to scour out relatively deep channels. Thus the channel of Great Machipongo Inlet between Hog and Cobbs islands is in places over 60 feet in depth while that of Sand Shoal Inlet between Cobbs and Bone islands has a maximum depth of 72 feet. The bars and hooks formed off

the mouths of these inlets and built up largely of material carried out from the lagoons are very changeable so that the buoys marking the channel approaches must be frequently shifted.

The lagoons are only temporary features as they are gradually being filled by the accumulation of vegetable material, by the debris carried from the mainland, and to a certain extent by the sand carried by the wind from the sandy beaches. If the land remains at its present level with respect to the ocean, these lagoons will ultimately disappear by this infilling and the sandy islands will be connected with the mainland as they are along many parts of the Atlantic coast at the present time.

SUBAERIAL DIVISION.

GENERAL CHARACTERISTICS.

The emerged portion of the Coastal Plain declines with gradually lessening slope from the Piedmont Plateau border to the shore-line. The highest portions of the Virginia Coastal Plain are found in Fairfax County near Washington. Southward the Western margin gradually declines in altitude. The outlier in Fairfax County already referred to covers a flat-topped divide almost 500 feet above sea level, while in Spottsylvania County similar deposits are found about 400 feet above sea level. In the southern portion of the State the greatest elevation of Coastal Plain deposits is probably little more than 200 feet. These differences in elevation are responsible for the much more diversified topography in the northern than in the southern portion of the State. The easterly slope of the Coastal Plain from the "fall-line" which near the western margin may reach 10 or 15 feet to the mile, or even more, gradually declines to less than a foot to the mile in the extreme eastern part of the State. On either side of Chesapeake Bay there are wide areas of monotonously flat lands only a few feet above the water level. The average elevation of the Virginia Coastal Plain is slightly more than 100 feet above tide.

TERRACES.

The topography of the Virginia Coastal Plain, although of low relief. is in reality more complex than at first appears, this complexity being due to a series of terraces which stretch across the region, each in succession wrapping about the preceding in concentric arrangement. These terraces are five in number and have been designated by the names of the formations whose deposits cover them. They are in order, from the highest to the lowest, the Lafayette, the Sunderland, the Wicomico, the Talbot, and the Recent.

Lafayette terrace.—The highest of the five terraces is known as the Lafayette. It is best developed in Virginia along the western margin of the province, capping the broader divides between the main streams. The surface of this terrace varies considerably in appearance according to its position. In some places in the interior of large areas where it is removed from the influence of streams, it is as flat and featureless as any portion of the Eastern Shore, but along the margins where it has been dissected by waterways, it has been transformed into a gently rolling country. Erosion has been so active since the formation of the Lafayette terrace that isolated remnants of the original surface are frequent, some of them occurring as outliers upon the Piedmont rocks, while other detached areas lie to the east of the main body. Could the intervening areas be filled in, we would have a continuous, gently-rolling to flat plain of variable width, extending from eastern Pennsylvania southward to Mexico.

The general slope of the Lafayette terrace is eastward toward the ocean and represents, as will be explained later, the gradual descent of a subaqueous terrace away from the shore-line out into deeper water. In some places the terrace has been slightly warped by earth movements and thus the normal slope is obscured. The highest portion of the Lafayette terrace thus far recognized in Virginia lies to the west of Falls Church in Fairfax County and has an elevation of between 480 and 500 feet above sea level. It gradually descends from this point to the eastward along the stream divides to an altitude of about 200 feet, where it ends at the escarpment marking the landward margin of the Sunderland terrace Added details regarding the distribution and character of this terrace will be given under the discussion of the Lafayette formation.

Sunderland terrace.—Bordering the Lafayette terrace at a lower level is the Sunderland terrace. It penetrates the former in re-entrants and is at times separated from it by a well-marked scarp line. This terrace surface has its greatest development in the central part of the province. From Stafford County to Greenesville County it is represented as a fringing terrace along the sides of larger valleys whose divides are formed by the Lafayette terrace. This relationship of the Sunderland to the Lafayette terrace is always found wherever the two occur in juxtaposition. The difference in altitude between them varies, generally becoming more marked to the westward toward the Coastal Plain border. The passage from the Lafayette to the Sunderland is gentle, but occasionally it is accomplished by means of an abrupt drop resembling in appearance a sea-cliff which has been more or less modified by subaerial erosion.

The same description applies to the surface of this terrace as to that of the Lafayette, namely, that in the interior where it has not been greatly affected by erosion, it still retains its original level, featureless character, but along the borders where it has been attacked by the headwaters of streams it has been transformed into a rolling country.

The Sunderland terrace reaches an altitude of about 200 to 250 feet above sea level where it abuts against the Lafayette terrace. From that line the surface slopes toward the larger streams as well as seaward, sometimes at the rate of several feet to the mile, at other times at the rate of only a few inches to the mile. In general, it may be stated that the greater portion of the Coastal Plain area of Virginia lying between 100 and 200 feet above sea level belongs to the Sunderland terrace. Could the Coastal Plain of Virginia be depressed 200 feet permitting the waters of the sea to cover the entire region below that elevation, the shore-line would more or less definitely define the present landward margin of the Sunderland terrace. Could the region then be uplifted 100 feet the resulting shore-line would approximately mark the eastward limit of the terrace.

Wicomico terrace.—Bordering the Sunderland terrace at a lower level is the Wicomico terrace. It bears the same relationship to the Sunderland terrace that the latter does to the Lafayette terrace in that it wraps about it as a border, extends up the larger stream valleys, and is separated from it by a well-defined line of low cliffs, especially in the northern portion of the State. In the eastern portion of the State from Northumberland County to Nansemond County it forms most of the flat-topped stream divides, while it is continued westward along the larger streams to the head of tide. The Wicomico terrace has suffered from erosion although less than the two older terraces but like them it no longer forms a continuous plain. In some places where streams have not yet cut the terrace it has a very flat surface, but elsewhere considerable portions have been entirely removed or cut up into a rolling country. The Wicomico terrace at its landward margin where it is in contact with the Sunderland has a nearly constant altitude of from 80 to 90 feet. From that line it slopes gradually eastward and to the larger valleys ending at the escarpment which represents the shore margin of the next lower or Talbot terrace.

Talbot terrace.—The lowest of the subaerial terraces is the Talbot. Like the other members of the series, it wraps about the preceding terrace like a border, penetrates it in re-entrants and is separated from the Wicomico terrace by a scarp line. This scarp line is very conspicuous in many parts of the region, sometimes with a height of 20 or more feet, at other times with

a height of less than 10 feet. It is very prominent just to the west of the Dismal Swamp and in many places in the valleys of the estuaries. The Talbot terrace occupies practically the entire counties of Mathews, Elizabeth City, Norfolk, and Princess Anne on the Western Shore and all of the Eastern Shore. It is found also as a bordering terrace, more or less continuous, along most of the estuarine portions of the Potomac, Rappahannock, York, and James rivers. It has suffered less from erosion than any of the other terraces, because of its lower altitude and more recent formation, and maintains nearly everywhere its original surface almost unmodified by the present drainage.

The Talbot terrace although in general monotonously flat, contains some shallow depressions, the most noted of which is that occupied by the Dismal Swamp. In other places, especially on the Eastern Shore and in Princess Anne County, the surface has been rendered more or less irregular by recent sand dunes. The altitude of the Talbot terrace, where it abuts against the Wicomico terrace is usually about 40 feet. From its landward margin it slopes away toward the surrounding waters where it either terminates in a wave-cut cliff or else passes down to tide level and merges with the modern beach.

Recent terrace.—The lowest or Recent terrace is almost entirely confined to the submerged portion of the Coastal Plain. It is in process of formation in the large estuarine streams and in Chesapeake Bay and is continuous with the submarine portion of the Coastal Plain previously described. Wave action and currents are furnishing materials that are being deposited along the margin of the present shores. Parts of this terrace are submerged beneath many feet of water while other portions are only submerged during times of high tide. These latter areas constitute the tidewater marshes which are so well developed along the short estuaries on either side of Chesapeake Bay and occasionally from large areas several square miles in extent along the larger estuaries many miles distant from the Bay. These marsh areas are constantly being built up by the annual accumulations of vegetable debris and also receive mud deposits during seasons of flood. Other portions of the Recent terrace receive the sediments brought down by the streams and also in places the accumulation of oyster shells. Could the Recent terrace be exposed, there is no reason to believe that it would appear essentially unlike that of the Talbot. It would be a monotonously flat plain with gentle slopes toward the channels of the present estuaries and separated in many places from the Talbot by a low escarpment.

SAND DUNES.

In various places both on the eastern and western shores of the Chesapeake Bay there are accumulations of wind-blown sand of recent origin. These are most abundant where the surface soils are composed of loose fine sand but they also occur along the ocean border where they have been built up from beach sand. Most of these sand dunes are low banks of sand, seldom more than 10 feet in height and arranged in long windrows at right angles to the usual trend of wind movement. In general the lee side of a sand dune is steeper than the windward side. Many observations of the low dunes on the Eastern Shore show them to have a general northeast and southwest direction, those some miles from the ocean front having the steeper side to the southeast, indicating that the northwest winds of winter the much more influential in their formation than are the prevailing southwesterly winds of the summer season.

The largest dunes of the Virginia Coastal Plain are the beach dunes along the ocean and bay shores in the vicinity of Cape Henry. These parallel the shore for a distance of several miles and are composed of the beach sand blown inward by landward-moving winds. The dunes at Cape Henry reach an elevation of 70 feet. The ocean slopes are very gentle while the landward slopes are steep. These dunes are advancing landward and are now encroaching upon a forest, some of the trees of which have already been buried. The movement, however, is a very slow one as the present condition of the dunes is not very different than when described by B. H. Latrobe[a] in 1799.

DRAINAGE.

An almost complete surface drainage system has been developed in the Virginia Coastal Plain although the topography is comparatively recent. There are a few natural fresh-water lakes or ponds while fresh-water marshes are almost entirely confined to the borders of the sluggish streams. The Dismal Swamp and Lake Drummond are the notable exceptions, yet they are not the only ones, for in some places there occur over the higher-lying divides small undrained areas in which the surface water collects during the rainy season to form small ponds or swamps which are desiccated during the summer months. Usually, however, the surface soil and subsoil are so porous that underground drainage is effected when the surface drainage system is incomplete. It is thus that considerable areas to the southeast of Norfolk are drained.

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[a]Trans. Amer. Philos. Soc., 1799, Vol. iv, pp. 439-444.

The upper and lower courses of those streams whose sources are in the Piedmont Plateau but which cross the Coastal Plain are in striking contrast. In the hard crystalline rocks they have cut narrow steep-sided valleys and their channels are frequently filled with great boulders producing falls and rapids, while in the loose sediments of the Coastal Plain the valleys are wide and open, the streams frequently bordered by extensive flood plains with no obstacles to disturb the quiet sluggish flow of the low-gradient streams. Within the Piedmont Plateau and at its margin the large as well as the small streams furnish considerable water power, but in the Coastal Plain all the water power is furnished by the small tributary streams.

Within the Coastal Plain the streams have series of branches formed at approximately right angles to the next larger stream and producing a stream system somewhat similar to the branchings of a tree and therefore known as dendritic.

Stream courses.—The drainage of the Virginia Coastal Plain is simple in that neither the geological structure of the region nor the materials through which the streams have cut their valleys have had much influence upon the present stream courses. The initial slopes of the region have determined the direction of the streams, and as the general slope is toward the east or southeast all of the leading streams flow in that direction. In the vicinity of the "fall-line," however, many of them are deflected sharply to the right and flow almost due south for a distance of from 5 to 30 miles before finally cutting across the Coastal Plain in their direct course to Chesapeake Bay. It appears as if the superimposed streams of the Piedmont Plateau, after having maintained their straight courses in the hard crystalline rocks had encountered serious obstacles in the great deposits of unconsolidated materials in the Coastal Plain and had found an easier passage southward. It has been claimed by some investigators that the "fall-line" is a line of fracture and faulting and that the stream courses have been affected in consequence. The few small faults which have been observed in the overlying Coastal Plain deposits along this line and the greater slope of the formations suggest earth movements of greater magnitude here than elsewhere and these movements may have influenced the present position of the streams. It seems more probable, however, that the main cause is due to the relative ease with which the basal Coastal Plain deposits are eroded in comparison with the overlying beds. Notwithstanding the fact that with local exceptions all of the Coastal Plain deposits are unconsolidated, some are much looser and are removed by erosion much more readily. The beds of the Potomac group which outcrop in a narrow

belt along the "fall-line" seem to resist stream erosion less than any of the other Coastal Plain formations. As a result the streams on entering the Coastal Plain province follow the outcrop of these beds for several miles. The best exposures of the Potomac beds are found along the Potomac, Rappahannock, North Anna, and James rivers in that portion of their courses where they flow in a southerly direction. The same conditions appear on the Appomattox River below Petersburg and in the Nottoway River in Sussex County except that these streams flow northward on the same beds, possibly due to an initial northerly slope in this portion of the Coastal Plain area. The Chickahominy agrees with the streams first mentioned above in flowing in a southerly course for several miles on reaching the Coastal Plain. Thus far the Potomac beds have not been observed along this part of the Chickahominy, but it is not improbable that they are there present but concealed from view by the more recent deposits which fill the valley.

Tide-water estuaries.—The most prominent features of the drainage of Virginia are the broad tidal estuaries which penetrate the State to the "fall-line" and divide the Coastal Plain region into a series of long, narrow peninsulas. These deep tidal streams have always contributed to the natural wealth of the State through the water products—oysters, crabs, and fish—which they have yielded in such great quantities, and also through the easy transportation which they have afforded for the products both of land and sea. When water transportation was practically the only means of conveyance the importance of these navigable streams was much greater than at present and for that reason tide-water Virginia was first brought under cultivation and during the 17th and 18th centuries was the leading section of the State. Foremost in importance among these bodies of water is Chesapeake Bay, while tributary to it are the long estuaries of the Potomac, Rappahannock, and James, between 150 and 200 miles in length and the shorter ones of the York, Wicomico, Piankatank, and Nansemond rivers and Mobjack Bay, besides hundreds of others of lesser importance. These all represent ancient valleys cut by streams when the country stood at a higher level than at present and which have been converted into their present condition by a depression of the country which permitted the waters of the sea to enter their valleys. In most of these estuaries the position of the former streams can be determined by the deeper channels but in some cases these have been obliterated by the deposits which have been laid down in them since their submergence. As little erosion takes place below tide level, it is possible to gain some idea of the amount of subsidence which has given rise

to the present estuaries from the depths of the deepest portions of the channels. The greatest depths of the lower Chesapeake Bay are about 150 feet in the vicinity of Cape Charles City. Thus we feel confident that when the depressions of the estuaries now filled with the tidal waters were excavated, the country must have been at least 150 feet higher than at present and probably much higher since the old channel has been traced eastward of the capes in water of considerably greater depth.

The water in the lower portions of all these estuaries is almost as saline as the sea water but in ascending the streams the water becomes brackish and near the head of tide is essentially fresh. The terms river and creek as applied to these estuaries seem to be misnomers since throughout most of their courses the upward-moving tidal flood-current is almost as pronounced as the downward current which is a combination of the normal flow of the stream and the ebb tide. A difference is noted, however, as one ascends the streams in the relative duration of flood and ebb tide. For example, at the mouth of the Rappahannock River the mean duration of flood tide is 5 hours and 50 minutes and of ebb tide 6 hours and 35 minutes while at Fredericksburg in the upper part of the estuary the current moves down stream almost all the time.

The slow currents in the estuaries are not strong enough to transport the materials brought in by the side tributaries and as a result the estuaries are being rapidly filled. Every heavy rain causes an immense amount of mud to be carried down by the side streams, nearly all of which is dropped before the water passes into the ocean. Sometimes for weeks at a time the water in the Potomac, Rappahannock, and James rivers will have a distinctly muddy color because of the great quantity of fine particles held in suspension, a large part of which is deposited before the waters enter Chesapeake Bay. In the early days many of the streams were navigable many miles above the points where vessels are now able to go, while in other streams the channels can only be kept open by dredging. The width of the estuaries is also decreasing due to the encroachment of the marsh areas which so commonly border these streams.

Marshes or terraces do not everywhere border the estuaries, for in many places there are steep, almost vertical bluffs of considerable height which afford excellent exposures of the underlying rocks. These are formed where the meandering streams have cut away the lower-lying terraces and opposite them are almost invariably extensive marsh areas. In Westmoreland County the Nomini Cliffs, which extend for several miles along the Potomac River and reach a maximum elevation of 200 feet, are the highest bluffs in the

Coastal Plain of Virginia and probably the highest in the entire Atlantic Coastal Plain province. Although somewhat lower the cliffs at Carters Wharf on the Rappahannock River, at Mt. Folly and Yorktown on the York River, at Drewrys Bluff, Howlett House and Kings Mill on the James River, and at Point of Rocks on the Appomattox River are equally picturesque.

Minor streams.—Entering the head of almost every estuary and flowing into them from the side are tributary streams of varying lengths which have not yet cut down to tide and which have sufficient fall to furnish considerable water power. Hundreds of these, all through the region, have been dammed and used to generate the motive power for grist and saw mills. Not infrequently these streams have very deep, steep-sided valleys and where they are numerous the country is decidedly rugged. On the Potomac River side of King George County there is such a region.

A marked peculiarity is noticeable in the relative lengths of these minor streams draining opposite sides of the peninsulas. On the Northern Neck, the region between the Potomac and Rappahannock rivers, the divide lies very close to the Potomac River and as a result the streams flowing into the Potomac are short, swift streams with precipitous valleys, while those flowing into the Rappahannock are longer, descend from the upland in easier stages, and have more open valleys. The same features are observed in the peninsulas between the Rappahannock and York rivers and between the York and James rivers, while more than three-fourths of the region lying to the south of the James River is drained southward into the Chowan River of North Carolina. The unsymmetrical location of the divides shows that the southward-flowing streams with their greater drainage areas have been enabled to cut back into the divides more rapidly than have the streams flowing to the north. This condition of affairs has probably been brought about by a slight tilting of the whole region to the southward or southwestward although an attempt has been made to find an explanation for this phenomenon from the effects of the earth's rotation.

The Dismal Swamp.—A discussion of the drainage of Coastal Plain Virginia should include a description of the Dismal Swamp. The statement which follows is taken from the Norfolk folio, U. S. Geological Survey, by N. H. Darton, who has made an exhaustive study of the district.

"The larger portion of this great fresh-water morass lies in the Norfolk quadrangle. It is an area of moderately elevated, nearly level land with such imperfect drainage that it remains constantly inundated to a slight depth. The outlines of the swamp area are irregular and usually the limits

are not well defined, the position of the edges of the wet portion varying with the rainfall and the presence of the swamp flora. Some marginal areas which are cleared have ceased to be swampy except in wet weather. The swamp is heavily wooded and contains extensive canebrakes. The swamp, which slopes gradually upward to the southwest, varies in altitude from 12 to 22 feet above mean tide level. Near its center there is a picturesque body of open water, known as Lake Drummond. This lake is nearly circular in outline, about 2¾ miles in diameter, and until recently its surface was slightly over 22 feet above mean tide level, being the highest portion of the swamp. At one time its depth was about 15 feet, due in part to the damming of the swamp by banks of canals. Now, owing to the deepening of the canal feeder, the lake is only about 6 feet deep and the surface correspondingly lower than it is known to have ever been before. Its floor is largely covered with white sand. The lake water is light brown in color, due to a considerable amount of finely divided vegetal matter in suspension. It is thought to be perfectly wholesome, and as it is famous for its keeping properties it has been used extensively for supplying ships for long voyages. The lake is surrounded by woods, and at some points cypress trees are found growing in the water. The depth of the water decreases rapidly in the woods adjoining the lake, and over the swamp area in general it is rarely more than 1½ feet, except possibly in very wet weather. The average depth is from 1 to 3 inches, but in many portions the average depth is from 6 to 8 inches. In very dry seasons the amount diminishes all over the swamp area.

"Some marginal portions of the swamp have been drained for farming land, for which the soil is admirably adapted. The swamp area known as the Green Sea was originally a portion of the main swamp, but the Dismal Swamp Canal, which traverses the eastern portion of the area from north to south, has in a measure drained the intervening region. This canal sustains the water level and the resulting swamp conditions to the west, but has reclaimed from inundation a zone of considerable width to the east, an area which is further drained by the branch ditch known as the Herring Canal. The swamp flora is characterized by the occurrence of bald cypress, juniper, black gum, and extensive canebrakes.

"The swamps lie in shallow basins in the surface of the general terrace of the Norfolk region. The basins are now filled to the general level of the surrounding country with vegetal accumulations, which have a maximum thickness of about 20 feet. In recent excavations for a gate on the feeder about half a mile east of Lake Drummond there were exposed 10 feet of

peat filled with roots and tree trunks, lying on 8 feet of clear peat which merged with the overlying beds, and this in turn was underlain by fossiliferous sand of late Neocene age. The thickness of the swamp deposits decreases toward the periphery of the present swamp area, but so few excavations have been made along the border zone that the conditions of thinning are not known. The upper beds of peaty materials merge gradually into the sands of the adjoining area, so that no boundary line can be given.

"The basin of the Dismal Swamp owes its origin to an extensive depression in the surface of the Columbia formation. At first this hollow was probably a slough in the terrace surface. When the Columbia formation was deposited James River had essentially its present course, but emptied into open water some distance northwest of the swamp. Its main current appears to have built a bar or broad delta which extended eastward and thus built up the terrace plain that lies east and southeast of Norfolk. Between this delta and the steep slope at the edge of the highlands which lie a short distance west of the Norfolk quadrangle there remained an area of lowland, a slough which was not built up appreciably by the Columbia deposits. When the delta was uplifted it became a high terrace with good drainage conditions, while the slough became a swamp filled with luxuriant vegetation, and it has so continued ever since. At first, when the vegetation was young, relatively fine-grained peat accumulated, but as the forest grew older, roots and trunks were intermixed with the finer materials, and finally the depression was filled up to the general level of the country by these accumulations. It is now so remote from the larger drainage ways and so choked with canebrakes that its drainage is still very imperfect and the swamp conditions continue over nearly all the original basin area. Lake Drummond is no doubt the remaining portion of an original center pond, probably greatly encroached on by the forests and canebrakes. It is probable also that during some periods the lake was dry for a short time. Its bottom has been raised somewhat by vegetal accumulations, but probably its water level has just about kept pace with the general rise of the swamp surface."

GEOLOGY OF THE VIRGINIA COASTAL PLAIN

INTRODUCTORY.

The great body of deposits forming the Coastal Plain of Virginia has been laid down along the border of the Piedmont Plateau on the floor of crystalline rocks of which that district is composed. These deposits are very thin in the vicinity of the "fall-line," but the accumulation of materials gradually increases to the eastward until the thickness reaches several thousand feet. At Fortress Monroe a government well penetrates the entire thickness of the Coastal Plain, reaching crystalline rocks at a depth of 2246 feet. At first estuarine in character, these deposits were later of marine origin and continued to be chiefly such until the later geological epochs when the marginal deposits of the Pleistocene were laid down in the inclosed bays and estuaries of the dissected Coastal Plain.

Although composed of a succession of formations which represent nearly every period from the Cretaceous to the Recent, the Coastal Plain deposits do not succeed each other in a conformable series, nor do they possess the same strikes and dips. Differential movements took place that materially affected the attitude of the beds by which, in certain sections, the landward exposures of whole formations that appear in adjacent regions have been eliminated. Thus the Upper Cretaceous deposits, so well exhibited in Maryland, are gradually transgressed by the Eocene southward, shutting out the former throughout the entire area of outcrop in Virginia, although recognized in the deep-well borings at Fairport and Fortress Monroe.

In general the beds strike from north to south although some variation occurs. The strata have a general easterly dip, which changes from 50 feet in the mile in the lowest formations, about the slope of the crystalline floor on which the deposits rest to less than 5 feet in the mile in the highest deposits. With this relatively low dip the beds generally appear horizontal in any particular section and may be actually so locally, so that measurements must be extended over a wide area before the average dip of any particular formation can be determined.

Formations represented in the Virginia Coastal Plain.

Age	Formation	Group
CENOZOIC		
Quaternary		
Recent		
Pleistocene	Talbot Wicomico Sunderland	Columbia group
Tertiary		
Pliocene (?)	Lafayette	
Miocene	Yorktown St. Mary's Calvert	Chesapeake group
Eocene	Nanjemoy Aquia	Pamunkey group
MESOZOIC		
Cretaceous		
Upper Cretaceous		
Lower Cretaceous	Patapsco Patuxent	Potomac group

MESOZOIC

CRETACEOUS.

The Cretaceous deposits of Virginia constitute part of the basal sediments of the Coastal Plain and overlie the crystalline rocks of the Piedmont Plateau along its eastern margin. Well borings near the eastern border of the Coastal Plain have never penetrated deposits of earlier age overlying the floor of crystalline rocks although they may exist still farther to the eastward beneath the submarine portion of the Coastal Plain. The Virginia deposits of this age are confined entirely to the Lower Cretaceous along the line of outcrop, although Upper Cretaceous deposits have been recognized in the deeper well borings. Where exposed at the surface these Lower Cretaceous sediments have been transgressed by the Tertiary formations, either Eocene or Miocene deposits overlying them uncomformably, as the case may be, although in the absence of the latter the Quaternary deposits often rest immediately on the Cretaceous beds.

LOWER CRETACEOUS.

BY

EDWARD W. BERRY.

THE POTOMAC GROUP.

Along the eastern border of the Piedmont Plateau, lying for the most part directly on the flanks of its ancient crystallines and constituting the basal element of the Atlantic Coastal Plain. is a series of mostly unconsolidated, arenaceous, arkosic, argillaceous and often ferruginous or lignitic sediments of highly varied character. Their outcrop constitutes a relatively narrow belt, extending from Pennsylvania to Alabama and ranges from a few to 20 miles in width, its landward boundary lying somewhat westward of the "fall-line". The thickness of the beds at the point where they pass beneath tide, ranges from 100 to 1,000 feet, dependent largely upon whether the full sequence of formations is present or not, although the formations themselves are very variable in thickness.

The flora of these deposits is a highly varied one consisting of equiseta, numerous ferns, cycads and conifers, a few monocotyledons, and a considerable variety of dicotyledons especially in the upper beds. The known fauna is a meagre one including a few pelecypods and gastropods of brackish water or estuarine habitat, a single fish and a considerable number of reptiles, especially dinosaurs. From the Arundel formation in the Maryland area both gigantic and diminutive forms of this order have been collected as well as the remains of stegosaurs and crocodilians.

That the Potomac sediments were laid down as terrestrial, lacustrine and fluviatile sediments, combined with contemporaneous deposits in shallow water along the Lower Cretaceous shore-line, is indicated by the absence of any strictly marine fossils and sediments, and by the presence of a few estuarine species of shells, and by the abundance of delicate plant remains often but slightly if at all triturated. The fossil wood is also frequently silicified or lignitized without having suffered much from decay. The coarseness of a large proportion of the materials, the frequency of marked current bedding, and the presence of a large amount of coarse gravel or even cobbles, effectually confirms the littoral and estuarine conditions under which the Potomac formations were deposited.

The deposits constituting the Potomac group were at first thought to constitute a single formation and in 1886 Dr. W J McGee[a] applied the name Potomac to them because of their extensive development in the Potomac River basin near Washington. Later investigations in Maryland have clearly demonstrated the fact that these deposits do not constitute a single formational unit, and in 1897 Clark and Bibbins[b] proposed a fourfold classification which has now come to be generally accepted. The formational names in order from the oldest to the youngest were the Patuxent, the Arundel, the Patapsco, and the Raritan. More recently the uppermost of these formations, the Raritan, has been referred to the Upper Cretaceous.

The Patuxent is the most constant from Maryland southward. The Arundel attains a considerable development in central Maryland, but disappears to the northward in northeastern Maryland and to the southward in southern Maryland. The Patapsco is largely developed from Delaware to the vicinity of Fredericksburg, Virginia, where it disappears. The known Raritan extends from the islands off the southern coast of New England to southern Maryland where it is transgressed by much later deposits of Tertiary age.

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[a] Report of Health Officer, D. C., 1884-5 (1886), p. 20.

[b] Jour. of Geol., vol. v, pp. 479-506.

Fig. 1.—Bluff at Dutch Gap, James River, looking upstream. Showing Patuxent formation overlain by Pleistocene deposits.

Fig. 2.—Bluff at Dutch Gap, James River, looking downstream. Showing Patuxent formation overlain by Pleistocene deposits.

PATUXENT FORMATION OVERLAIN BY PLEISTOCENE DEPOSITS.

The total exposed thickness of the Potomac formations in Virginia in the region of their outcrop is about 500 feet. The formations thicken down the dip to the eastward, and in all probability the Raritan also, although undifferentiated, is present beneath the Tertiary cover. At Fortress Monroe the combined thickness of the Potomac formations, penetrated in the new government well, is about 1,300 feet.

The Patuxent Formation.

Name.—The Patuxent formation, so called from the Patuxent River, Maryland, where the deposits are well exposed, constitutes the basal portion of the Potomac group.

Stratigraphic relations.—The Patuxent beds rest throughout most of their area, with marked unconformity, upon the crystallines of the Piedmont and the contact is observable at numerous outcrops. In a limited area around Doswell the Patuxent rests upon the Triassic. In most of the region from Alexandria to Fredericksburg the Patapsco unconformably overlies it. South of Fredericksburg either the Eocene or the Miocene deposits directly overlie the Patuxent. The Lafayette and Pleistocene deposits also frequently cover the Patuxent outcrops along the larger valleys.

Lithologic character.—The materials composing the Patuxent are variable, the formation frequently changing its lithologic characters rapidly in both vertical and horizontal directions. The deposits consist chiefly of light-colored sands, sometimes almost entirely made up of pure quartz grains, but usually containing a large amount of kaolinized feldspar (arkose) resulting from the decomposition of granitic rocks in the region to the westward. Mica flakes derived from the same source are very abundant at certain localities as are also greenish clays which derive their color from the chloritic schists of the Piedmont. Above Dutch Gap along the James River certain beds composed of quartz, mica, and kaolin so closely resemble the residual materials resulting from the decay of the granitic rocks that the planes of stratification are almost the only clue to their real origin. The quartz grains are generally quite well rounded, although in some places, as in the locality above cited, they are decidedly angular. The sands locally become indurated, sometimes so firmly as to be of value as a building stone. Before the day of railroads these indurated layers were quarried in a number of places. At Aquia Creek the United States government in the early part of the last century quarried a sandstone from this formation for the construction of the White House, the old por-

tion of the Capitol, and other public buildings in Washington. The old lighthouse at Cape Henry is built of this Aquia freestone, as are also the local foundations, etc. On the north shore of the Rappahannock River just opposite Fredericksburg there is also a thick bed of Patuxent sandstone but the most extensive deposit of these indurated sands occurs at Point of Rocks on the Appomattox River below Petersburg. Here there is an indurated arkosic conglomerate, extending from the water's edge to the top of a nearly vertical bluff 80 feet in height. Some layers are very firmly cemented and the material from them has been quarried from colonial days for local use in the construction of walls and buildings.

Cobbles and boulders are not uncommon in the Patuxent deposits. Sometimes they form distinct beds while at other times they occur irregularly distributed throughout strata of finer materials. At the base of the Howlett House bluff on the James River opposite Farrar Island there is a conglomerate bed 30 feet in thickness of large and small cobbles and pebbles in a matrix of coarse arkosic sand, the whole locally indurated.

Although sands predominate in the Patuxent formation, clays are not altogether absent. The beds of sand occasionally pass into clay deposits while in other places the sand and clay beds are interstratified. The sandy clays frequently contain great quantities of lignitic material. In cutting the Dutch Gap canal on the James River a log of lignite about 60 feet in length and 10 inches in diameter is said to have been taken out. The Patuxent clays are seldom highly colored, so that they can generally be very readily distinguished from the variegated clays of the Patapsco formation. In the vicinity of Dutch Gap there are irregular masses of dark-colored clay embedded in the sandy strata. Some of these are several feet in diameter and are decidedly angular, showing that they were only transported a short distance. Many fine plant impressions frequently occur in them. The sands are almost invariably cross-bedded.

Strike, dip, and thickness.—The general strike of the Patuxent formation throughout Virginia is almost due north and south. The dip is to the east at the rate of nearly 50 feet to the mile in the region of the "fall-line", while farther to the eastward it decreases to about 30 feet to the mile. To the eastward of the line where the deposits disappear beneath the later sediments the dip has not been determined, except that at Fortress Monroe, 75 miles to the eastward the base of the Potomac deposits is reached at a depth of 2,246 feet indicating a still more gentle dip over this area. The floor of crystalline rocks upon which the Patuxent formation rests is very irregular so that the thickness of the deposits is extremely variable. This is

well shown along the James River where just below Richmond the Patuxent deposits extend to tide, while about a mile and a half above Dutch Gap the crystalline rocks reappear along a small stream which empties into the James River. The Patuxent beds where they have been differentiated at the outcrop have a thickness of from 250 to 300 feet.

Paleontologic character.—Although the Patuxent deposits are in general unfossiliferous because of their coarse character, nevertheless a large flora has been collected from clay balls and lenses and the more argillaceous sands. This flora has been elaborated by Professors Ward and Fontaine in various publications of the U. S. Geological Survey[a] and is undergoing revision by the writer at the present time.

It includes a large element made up of survivors from the older Mesozoic and is rich in species and individuals referred to the fern genera *Cladophlebis* and *Onychiopsis*. A variety of cycad fronds testify to the abundance of this type of plant and is emphazised by the presence of numerous silicified trunks in the Maryland area. Perhaps the most striking of the cycad remains are the splendid fronds referred to the genus *Dioonites* which are extremely abundant in the Dutch Gap region. Other forms of cycads present include species of *Podozamites, Zamiopsis, Nilsonia, Ctenis, Ctenophyllum,* most of which are confined to the older Potomac and do not occur in the Patapsco deposits although some of them occur in the Arundel formation in Maryland.

Among the conifers are species of *Baiera, Brachyphyllum, Sphenolepis, Frenelopsis, Nageiopsis, Arthrotaxopsis* and *Cephalotaxopsis,* representative of various subfamilies which in the modern flora are largely natives of other continents. Supposed Angiosperms, the most ancient known, are represented by the archaic genera *Rogersia, Proteaephyllum,* and *Ficophyllum,* which may well represent the foliage of some Lower Cretaceous member of the Gnetales and not angiospermous plants, a point not yet definitely settled.

Areal distribution.—The Patuxent formation has been recognized chiefly in the Chesapeake Bay drainage basin in Maryland and Virginia, although the Nottaway River exposures in southern Virginia are very probably referable to this formation.

In the Virginia area the Patuxent formation is found near the head of tide in the leading drainage basins lying directly upon the very uneven floor of crystalline rocks which constitute the eastern margin of the Pied-

[a]Monograph XV, 1889, 4°, XIV, 377 pp., 180 pls. Fifteenth Ann. Report, 1893-94. Monograph XLVIII, 1906.

mont Plateau. The outcrop is more or less continuous from Washington to the Rappahannock River at Fredericksburg. South of Fredericksburg exposures are seen only along the banks of the larger streams. In the vicinity of Doswell it outcrops along the North Anna River for a distance of several miles above the confluence with the South Anna River which unites with the former to form the Pamunkey. In the vicinity of Richmond the Patuxent is exposed almost continuously along the banks of the James River from the State capitol to Jones Neck a few miles above Bermuda Hundred, exhibiting a number of most excellent exposures, notably at Drewrys and Chaffins bluffs and in the vicinity of Dutch Gap. In the Petersburg region the Patuxent outcrops along the Appomattox River at intervals from that town to within a short distance of its junction with the James River at City Point. Numerous exposures are to be observed, notably at Point of Rocks. The most southerly exposures of the Patuxent in Virginia are found to a limited extent in the valley of the Nottoway River in western Sussex County, although these have not been seen by the writer. No other river in southern Virginia has succeeded in cutting a channel to the Potomac surface, although it may be noted that unmistakably reworked Patuxent materials are abundant in the Pleistocene in the vicinity of Emporia. South of the Virginia line the Patuxent formation extends across North Carolina, broadening out to a remarkable extent in the upper Cape Fear basin around Fayetteville.

The Arundel Formation.

(NOT RECOGNIZED IN VIRGINIA.)

The Patuxent formation is succeeded in the Maryland area by a series of stratified clay beds, fine in texture and brown in color, carrying a large amount of carbonaceous matter and considerable deposits of iron ore which were used extensively in colonial days. These beds, long known as the "iron ore clays," contain a varied flora scarcely distinguishable from that of the Patuxent formation, and a considerable, chiefly dinosaurian, fauna which finds its counterpart in the Morrison beds of the West and the Wealden of Europe.

The Arundel deposits are thought to represent discontinuous swamp and lagoon accumulations in warped valleys of post-Patuxent time and are therefore unconformable upon the older beds. They owe their iron to the fact that their sediments were largely derived from the decay of gabbro and other iron-rich crystallines lying immediately to the westward of the

Fig. 1.—Cut on R. F. & P. R. R. near Cockpit Point. Showing sandy beds of Patuxent formation.

Fig. 2.—Cut on R. F. & P. R. R. near Cockpit Point. Showing sandy beds of Patuxent formation.

SANDY BEDS OF PATUXENT FORMATION.

area of their most extensive development, while in the Virginia area the source of the Potomac sediments were the granitic and gneissoid rocks which there constitute the eastern Piedmont.

The Arundel is typically developed in the area between Baltimore and Washington in Anne Arundel and Prince George's counties, Maryland. It is also present in Baltimore City and in Baltimore and Harford counties but has not been recognized farther to the northeast in Cecil County, Maryland, or to the southwest in the valley of the Potomac River.

The Patapsco Formation.

Name.—The Patapsco formation receives its name from the Patapsco River, Maryland, in the valley of which excellent exposures of these beds are found.

Stratigraphic relations.—In Maryland the deposits of the Patapsco formation rest unconformably upon the Arundel where it is present and in other places upon the Patuxent formation or the crystallines of the Piedmont Plateau. Throughout their area of outcrop in Virginia the Patapsco deposits rest with marked unconformity upon the Patuxent. In the stream valleys the deposits frequently have a covering of Pleistocene materials while Lafayette gravels, sands, and loam often cap it when it rises to the height of the stream divides. It disappears from view along the eastern margin of its outcrop beneath the Aquia formation of the Eocene, which is also found capping it in the higher hills and may be seen in several places in Stafford County about Aquia, Accokeek, and Potomac creeks.

The Patapsco was greatly eroded in pre-Eocene times, its upper surface being extremely uneven, this undulating contact, emphasized by the marine beds of the overlying Aquia formation, being one of the sharpest lines in the whole Coastal Plain.

From the record of the deep wells near the mouth of the James River, notably at Fortress Monroe, it is believed that the Upper Cretaceous deposits so extensively developed in Maryland and New Jersey intervene between the Patapsco and Aquia formations.

Lithologic character.—The Patapsco, like the Patuxent formation consists of very variable materials—clays, sands, gravels, and conglomerates. The deposits, however, are more uniform and finer than those of the Patuxent, consisting chiefly of highly colored and variegated clays, which grade over into lighter colored sandy clays, while sandy bands of coarser materials are at times interstratified. The sands frequently contain much decomposed feldspar and like those of the Patuxent are often cross-bedded.

and occasionally lithified. The Virginia deposits are in general much less highly colored than those of the Maryland region, a feature due to the absence of iron rich crystallines in the area from which their sediments were derived. The clays, like those of the Patuxent in Virginia are frequently greenish when unweathered, due to the presence of chlorite derived from the chloritic schists of the Piedmont.

Strike, dip and thickness —The strike of the Patapsco beds in Virginia is almost due north and south and the dip is about 30 feet to the mile to the eastward. The total thickness in the region of outcrop is about 150 feet, but this increases to the eastward beneath the overlying Tertiary deposits.

Paleontologic character.—The Patapsco deposits have yielded a few specimens of undeterminable unios and an extensive flora made up of ferns, cycads, conifers, monocotyledons and dicotyledons. The ferns, cycads, and conifers represent the dwindling remnants of the Patuxent and Arundel flora, quite a number of the older Potomac species continuing through the Patapsco as for example *Nageiopsis angustifolia* Font., and various species of *Cladophlebis, Onychiopsis, Sequoia,* and *Sphenolepis.* In other cases the same genera are represented by distinct species at the two horizons as in the genus *Acrostichopteris.*

A species of *Pinus* represented by seeds, cone-scales, and cones is one of the characteristic forms of this formation as are also the cone-scales referred to *Araucaria aquiensis* Font. The twigs of *Widdringtonites ramosus* (Font.) Berry are also a rather constant feature of the Patapsco fossiliferous outcrops and furnish a point of contact with *Widdringtonites Reichii* (Ett) Heer of the Upper Cretaceous. Other characteristic Patapsco forms are the various species of the dicotyledonous genus *Sapindopsis* and the fern *Knowltonella Maxoni* Berry. The marked distinctness of the Patapsco flora, however, rests mainly upon the great increase and modernization of the dicotyledons which foreshadow those of the Raritan.

The more characteristic of these are various species of *Sapindopsis, Celastrophyllum, Sassafras, Sterculia, Cissites, Aralæphyllum, Populophyllum,* etc.

Areal distribution.—The Patapsco formation has been recognized in isolated remnants in Pennsylvania and Delaware, it outcrops in a broad belt across Maryland, and continues southward into Virginia through eastern Fairfax, Prince William, and Stafford counties to the vicinity of Fredericksburg. It is most extensively developed in the valley of the Potomac River, appearing in numberless bluffs from Washington to where it finally disappears beneath the Eocene in the vicinity of Aquia Creek,

Fig. 1.—Bluffs above Widewater on Potomac River. Showing Patapsco formation overlain by Pleistocene deposits.

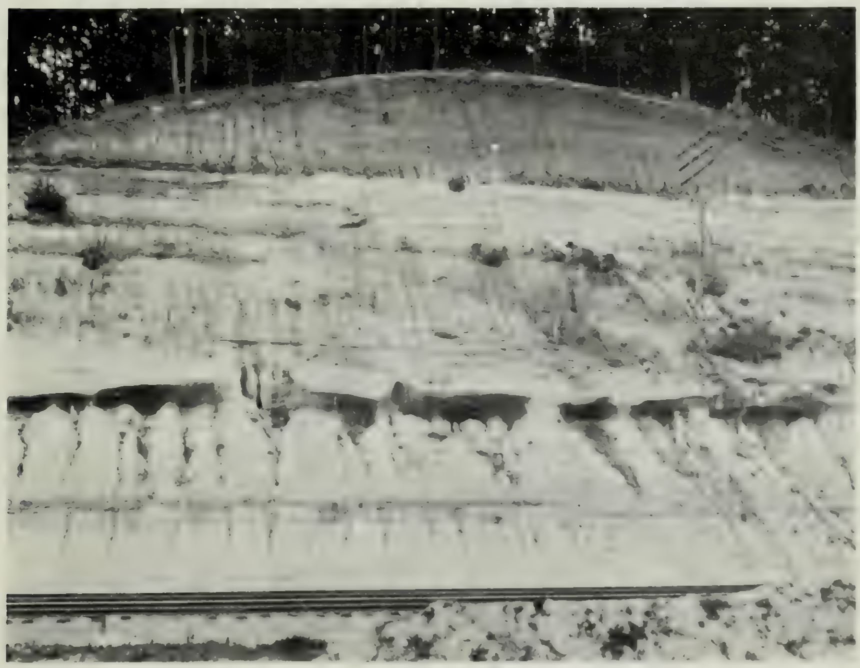

Fig. 2.—Cut on the R. F. & P. R. R. south of Aquia Creek. Showing Patapsco formation overlain by Aquia formation.

PATAPSCO FORMATION.

Virginia. The Patapsco is found on Potomac Creek about a mile below the railroad crossing and on Aquia Creek, in the vicinity of the railroad bridge, and at tide on the Rappahannock River near the mouth of the Massaponax River. There are also numerous exposures and fossiliferous outcrops in the area around Brooke. A single exposure of positively determinable age is found in the valley of the James River at Deep Bottom 4 miles below Dutch Gap canal at the most eastern point where the Potomac deposits appear above tide. From these points it rises rapidly to the west along the sides of the valleys and forms the tops of the hills, except for the thin covering of Eocene, Lafayette, or Pleistocene materials which overlie it.

DETAILED SECTIONS.

POTOMAC RIVER SECTIONS.

The Potomac strata outcrop at intervals along the Virginia bank of the Potomac River from Alexandria almost to the mouth of Aquia Creek. The first locality worthy of mention is on the Mt. Vernon estate a short distance below the steamboat landing. This and other exposures in the immediate vicinity and up Doag Creek are very poor and much covered, but as they are very fossiliferous they merit some description. At several points along the base of this bluff 10-15 feet of Potomac materials are exposed. These consist of arkosic, irregularly-bedded, light sands, more or less indurated with thin layers of more argillaceous materials brownish or pinkish in color and carrying leaf impressions which are usually somewhat contorted. The materials are all of Patapsco age and the more important forms found include the following:

Acrostichopteris longipennis Font.
Antholites Gaudium-Rosae Ward
Aralia ? vernonensis Font.
Aristolochiaephyllum ? cellulare Ward
Casuarina Covillei Ward
Celastrophyllum Brittonianum Hollick
Celastrophyllum Hunteri Ward
Celastrophyllum ? saliciforme Ward
Cladophlebis rotundata Font.
Ephedrites ? vernonensis Font.
Nelumbites tenuinervis (Font.) Berry
Nelumbites virginiensis (Font.) Berry
Nageiopsis angustifolia Font.
Nageiopsis longifolia Font. ?
Onychipsis Goepperti (Schenk) Berry
Pinus vernonensis Ward
Populophyllum minutum Ward
Populophyllum reniforme Font.
Populus potomacensis Ward
Potamogetophyllum vernonense Font.
Sagittaria Victor-Masoni Ward
Dicksoniopsis vernonensis (Ward) Berry
Sphenolepis Sternbergianum (Dunk.) Schenk
Thyrsopteris grevillioides (Heer) Hollick
Sterculia elegans Font. ?
Thinnfeldia Fontainei Berry
Widdringtonites ramosus (Font.) Berry
Zamites tenuinervis Font.

The next locality is at White House bluff about 2 miles below Mt. Vernon where the following section is exposed at intervals along the bluff:

I. *Section at White House Bluff.*

			Feet
Pleistocene		Ferruginous sand and gravel	10-20
		Ferruginous sand with cobbles up to 12 inches in diameter	5
Lower Cretaceous.	Patapsco	Gray or buff incoherent sand with thin lenses of reddish clay	15
		Pinkish or brownish sandy clay with tests of Estheria and leaf impressions including *Acrostichopteris longipennis* Font., *Araucarites aquiensis* Font., *Carpolithus brookensis* Font., *Celastrophyllum albaedomus* Ward, *Sapindopsis magnifolia* Font., *Sapindopsis variabilis* Font., *Dichotozamites cycadopsis* (Font.), *Sphenolepis sternbergiana* (Dunk.) Schenk and *Widdringtonites ramosus* (Font.) Berry	3-5
		Much cross-bedded and slightly arkosic coarse buff sand, somewhat argillaceous and with scattered pebbles and clay laminae	20-25
		Indurated much cross-bedded and very arkosic gray sand with scattered pebbles	20-25
		Total	73-95

On the south side of Gunston Cove opposite White House bluff the following section is exposed, the Potomac materials extending to the top of the bluff:

II. *Section of Gunston Cove Bluff.*

			Feet
Lower Cretaceous.	Patapsco	Massive buff or gray coarse sand	20
		Gray incoherent irregularly-bedded sand alternating with thin lenses of brownish sandy clay carrying undeterminable plant remains	40
		Greenish sandy chloritic clay weathering to reddish and purplish mottled colors becoming sandy above	20
		Total	80

The next exposure of any extent below Gunston Cove is that at Freestone Point, which, by combining the exposures along the river with those in the deep cut of the R. F. and P. R. R. at this point, give the following section:

III. *Section at Freestone Point.*

		Feet
Pleistocene	Light cross-bedded iron-stained sands with pebbles and clay pellets	0-20
Eocene. Aquia (?)	Argillaceous greensand	4-8
Lower Cretaceous. Patuxent	Gray cross-bedded coarse arkosic sand with indurated ledges and scattered pellets and lenses and balls of greenish argillaceous materials, very variable horizontally and vertically	40-50
	Gray indurated cross-bedded arkosic sand	30
	Total	74-108

IV. *Section at Cockpit Point.*

		Feet
Pleistocene	Iron-stained sandy loam with gravel at the base	15-20
Lower Cretaceous. Patuxent	Buff cross-bedded sand with some lignite and a few clay balls, carrying leaf impressions in the more argillaceous layers. These include *Cladophlebis parva* Font., *Dioonites Buchianus* (Ett) Born., *Equisetum Burchardti* (Dunk.) Brongn., *Feistmantelia oblonga* Ward, *Nageiopsis zamioides* Font., *Nageiopsis longifolia* Font., *Podozamites* sp., *Scleropteris elliptica* Font., *Sequoia ambigua* Heer, *Sphenolepis Kurrianum* (Dunk.) Schenk, *Sphenolepis Sternbergiana* (Dunk.) *Onychiopsis Goepperti* (Schenk) Berry, etc.	18
	Greenish, massive, chloritic, sandy clay	10
	Total	43-48

This and the preceding are the only decisive exposures of Patuxent on the Potomac River and evidently owe their preservation to the resistant character of the Patuxent materials, which are firmly indurated, forming the well-known "freestone" formerly much quarried in this vicinity. The unconformable nature of the Patuxent-Patapsco contact is well shown, since about a mile south directly along the strike a characteristic Patapsco flora is found at a somewhat lower level.

V. *Section Dumfries Wharf just above Quantico Creek.*

			Feet
Pleistocene		Ferruginous sandy loam with gravel bed and boulders at the base......................	15
Lower Cretaceous.	Patapsco	Gray arkosic sand more or less indurated and cross-bedded below, with small lenses of sandy clay carrying leaf impressions including *Acrostichopteris longipennis* Font., *Brachyphyllum crassicaule* Font., *Sassafras* sp., *Sphenolepidis sternbergiana* (Dunk.) Schenk, *Zamites tenuinervis* Font., etc..................	6-10
		Total...............................	21-25

VI. *Section just above Widewater, Virginia.*

			Feet
Pleistocene		Sandy loam with gravel base...........about	10
Lower Cretaceous.	Patapsco	Coarse, arkosic, cross-bedded, partially lithified, somewhat argillaceous sand................	15-20
		Local unconformity with iron crusts. Chloritic sandy drab clay with leaf impressions including *Araucarites aquiensis* Font., *Sassafras sp.*, *Sapindopsis variabilis* Font., *Zamites tenuinervis* Font. etc., exposed to water..........	5-10
		Total...............................	30-40

The foregoing exposure is continuous along the river, the lithology being variable. About one-quarter of a mile above the section just given, the same flora is found above the unconformity, showing that it is purely local in character.

VII. *Section one-quarter of a mile above last.*

			Feet
Pleistocene		Sandy loam with gravel....................	8-12
Lower Cretaceous.	Patapsco	Argillaceous sand with lenses of brownish sandy clay carrying leaf impressions including *Araucarites aquiensis* Font., *Brachyphyllum crassicaule* Font., *Celastrophyllum acutidens* Font., *Feistmantellia oblonga* Ward, *Onychiopsis psilotoides* (Stokes & Webb) Ward, *Pinus vernonensis* Ward, *Populophyllum reniforme* Font., *Sapindopsis magnifolia* Font., *Sapindopsis variabilis* Font., *Saliciphyllum parvifolium* Font., *Sphenolepidium Sternbergianum* (Dunk.) Heer, *Zamites tenuinervis* Font. etc............................	15-10
		Local unconformity with iron crusts.	
		Coarse, arkosic, cross-bedded, argillaceous sand exposed to water........................	5-10
		Total...............................	28-42

RAPPAHANNOCK RIVER SECTIONS.

Exposures of the Patuxent are frequent in the vicinity of Fredericksburg, although they are for the most part covered with Eocene or surficial deposits. From Falmouth, about 1 mile above Fredericksburg, occasional exposures along the river show upwards of 30 feet of the arkosic gray sands of the Patuxent formation. A somewhat argillaceous lens of these materials near the steamboat landing at Fredericksburg yielded the large number of fossil plants for which this locality is famous. These have furnished the only adequate materials for a study of the Patuxent flora. The following are the more important forms identified from this locality:

Acrostichopteris adiantifolia (Font.) Berry
Acrostichopteris parvifolia Font.
Acrostichopteris pluripartita (Font.) Berry
Arthrotaxopsis grandis Font.
Carpolithus agglomeratus Font.
Carpolithus conjugatus Font.
Carpolithus curviatus Font.
Carpolithus fasciculatus Font.
Cephalotaxopsis brevifolia Font.
Cephalotaxopsis magnifolia Font.
Cladophlebis Albertsii (Dunk.) Brongn.
Cladophlebis distans Font.
Cladophlebis constricta Font.
Cladophlebis virginiensis Font.
Cladophlebis parva Font.
Cladophlebis Ungeri (Dunk.) Ward
Cladophlebis Browniana (Dunk.) Ward
Ctenis imbricata Font.
Ctenophyllum latifolium Font.
Ctenopteris insignis Font.
Ctenopteris longifolia Font.
Cycadeospermum ellipticum Font.
Dryopteris cystopteroides Font.
Dryopteris Dunkeri Font.
Equisetum Lyelli Mant.
Ficophyllum serratum Font.
Ficophyllum oblongifolium Font.
Frenelopsis ramosissima Font.
Leptostrobus longifolius Font.
Nageiopsis longifolia Font.
Nageiopsis angustifolia Font.
Nageiopsis zamioides Font.
Nilsonia densinerve (Font.) Berry
Onychiopsis goepperti (Schenck) Berry
Onychiopsis psilotoides (Stokes & Webb) Ward
Podozamites distantinervis Font.
Proteaephyllum ovatum Font.
Proteaephyllum reniforme Font.
Rogersia angustifolia Font.
Rogersia longifolia Font.
Ruffordia Goepperti (Dunk.) Seward
Sagenopteris virginiensis Font.
Scleropteris elliptica Font.
Sequoia ambigua Heer
Sequoia Reichenbachi (Gein) Heer
Sphenolepis Kurriana (Dunk.) Schenk
Sphenolepis Sternbergiana (Dunk.) Schenk
Taeniopteris auriculata (Font.) Berry
Taeniopteris nervosa (Font.) Berry
Thinnfeldia rotundiloba Font.
Thyrsopteris dentata Font.[1]
Thyrsopteris crenata Font.
Thyrsopteris divaricata Font.
Thyrsopteris crassinervis Font.
Thyrsopteris angustiloba Font.
Thyrsopteris heteroloba Font.
Thyrsopteris heteromorpha Font.
Thyrsopteris heterophylla Font.
Thyrsopteris nana Font.
Zamites crassinervis Font.
Zamites tenuinervis Font.
Zamiopsis insignis Font.
Zamiopsis laciniate Font.
Zamiopsis longipennis Font.
Zamiopsis petiolata Font.

Southeast of the town no Potomac materials are seen along the river for about 2 miles. Below this point, for a distance of about 6 miles or to about half a mile below the mouth of the Massaponax, the banks show

[1]These species of Thyrsopteris have not yet been restudied.

occasional exposures of the usual gray coarse arkosic and more or less lithified sandstone of the Patuxent, which rises from 10 to 15 feet above tide and is overlain for the most part by Aquia Eocene. At the mouth of the Massaponax the following section occurs.

I. *Section left bank of Rappahannock River, opposite mouth of Massaponax Creek.*

			Feet
Pleistocene		Sand and gravel......................about	12
Eocene.	Aquia	Weathered argillaceous greensand............	5
Lower Cretaceous.	Patuxent	Coarse arkosic sand with gravel and angular clay pellets............................	20
		Total..............................	37

The last exposure seen on the Rappahannock is along the right bank half a mile below Massaponax Creek, where the following section occurs:

II. *Section half mile below last, right bank.*

			Feet
Pleistocene		Mostly concealed.........................	20
Eocene.	Aquia	Poorly exposed glauconitic sand.............	22
Lower Cretaceous.	Patuxent	Coarse gravelly compact arkosic sand.........	12
		Total..............................	54

JAMES RIVER SECTIONS.

At Richmond the crystallines are exposed in the bed of the river, and their contact with the Patuxent is not seen, because of the low banks which are continuous for several miles below that town. Several low bluffs along the left bank between Richmond and Drewry's Bluff show a few feet of Patuxent arkosic argillaceous sands beneath 10 to 20 feet of Pleistocene. The section of Drewry's Bluff shows the best exposure of the Patuxent formation on the river and is continuous along the right bank for over half a mile. The lateral variation of the materials is considerable and affords an excellent idea of the marked changes in lithology which are typical of the Patuxent, particularly in this area.

I. *Section at Drewry's Bluff.*

			Feet
Pleistocene		Argillaceous, ferruginous sand	6
		Gravel bed	5
Lower Cretaceous.	Patuxent	Light gray coarse, arkosic sand	5-20
		Similar materials much cross-bedded and carrying gravel, cobbles, and clay balls	5-15
		Dark drab clay lenses in sand	5-10
		Indurated arkosic sand	12
		Coarse, arkosic, cross-bedded sand with clay balls and cobbles	15
		Total	53-83

As previously mentioned, the materials change so rapidly from point to point that no two sections of the bluff would be identical. The clay lens near the middle of the outcrop is very variable and the cobbles frequently tend to become aggregated into lenticular masses. Indurated layers a foot or two in thickness are also irregularly scattered through the bluff.

The next exposure is at Chaffin Bluff along the left bank one mile below the last.

II. *Section at Chaffin Bluff.*

			Feet
Pleistocene		Ferruginous, sandy clay	15
		Bed of cobbles	5
Lower Cretaceous.	Patuxent	Gray, arkosic sand	10
		Dark drab clay	15
		Total	45

This section also is extremely variable horizontally.

The next exposure about three miles below the last is along the right bank a short distance below Proctor Creek where the Patuxent is overlain by a remnant of Eocene materials.

III. *Section below Proctor Creek.*

			Feet
Pleistocene		Argillaceous, ferruginous sand ... about	10
		Course gravel with cobbles	8-10
Eocene		Glauconitic sands	5
Lower Cretaceous.	Patuxent	Indurated, coarse, arkosic, cross-bedded sands	10-15
		Total	33-40

Below this exposure a short distance the crystallines show along the right bank and they are also exposed in the bed of a small stream which flows into the left bank about one and a half miles above Dutch Gap canal, these limited outcrops constituting the most easterly appearance of the Piedmont rocks in this area.

For about two miles before reaching Dutch Gap canal low exposures of the Patuxent formation overlain by a considerable thickness of Pleistocene are exposed along the left bank. The materials are grayish arkosic, cross-bedded sands with numerous clay lenses, some of which have yielded fossil plants, notably a low exposure about one mile above the canal where the following species have been collected:

Abietites longifolius (Font.) Berry
Abietites foliosus (Font.) Berry
Abietites macrocarpus Font.
Acrostichopteris pluripartita (Font.) Berry
Acrostichopteris cyclopteroides Font.
Acrostichopteris parvifolia Font.
Baiera foliosa Font.
Carpolithus virginiensis Font.
Carpolithus geminatus Font.
Carpolithus latus Font.
Carpolithus sessilis Font.
Ceptalotaxopsis brevifolia Font.
Cephalotaxopsis magnifolia Font.
Cladophlebis virginiensis Font.
Cladophlebis distans Font.
Cladophlebis Browniana (Dunk.) Seward.
Cladophlebis Ungeri (Dunk.) Ward.
Cladophlebis Albertsii (Dunk.) Brongn.
Cladophlebis oblongifolia Font.
Cladophlebis sphenopteroides Font.
Cycadeospernum ellipticum Font.
Dioonites Buchianus (Ett.) Born.
Equisetum Burchardti (Dunk.) Brongn.
Equisetum Lyelli Mant.
Ficophyllum crassinerve Font.
Gleichenia nordenskioldi Heer
Nageiopsis longifolia Font.
Nageiopsis zamioides Font.
Onychiopsis Goepperti (Schenk) Berry
Phyllocladopsis heterophylla Font.
Podozamites acutifolius Font.
Proteaephyllum tenuinerve Font.
Rogersia longifolia Font.
Ruffordia acrodentata (Font.) Berry
Ruffordia Goepperti (Dunk.) Seward.
Scleropteris elliptica Font.
Sphenolepis Kurriana (Dunk.) Schenk
Sequoia ambigua Heer
Sequoia delicatula Font.
Thinnfeldia granulata Font.
Thyrsopteris brevipennis Font.
Thyrsopteris divaricata Font.
Thyrsopteris meekiana Font.
Thyrsopteria angustifolia Font.
Thyrsopteris angustiloba Font.
Thyrsopteris nana Font.
Thyrsopteris ineaquipinnata Font.
Williamsonia virginiensis Font.
Zamites crassinervis Font.
Zamites tennuinervis Font.

Dutch Gap canal, celebrated historically, is 17 miles below Richmond. It is only about 100 yards in length and cuts off an oxbow of seven miles. Low exposures of Patuxent materials are equally well exposed in both banks and show in the following section, the following figures being a diagrammatic representation of the east bank.

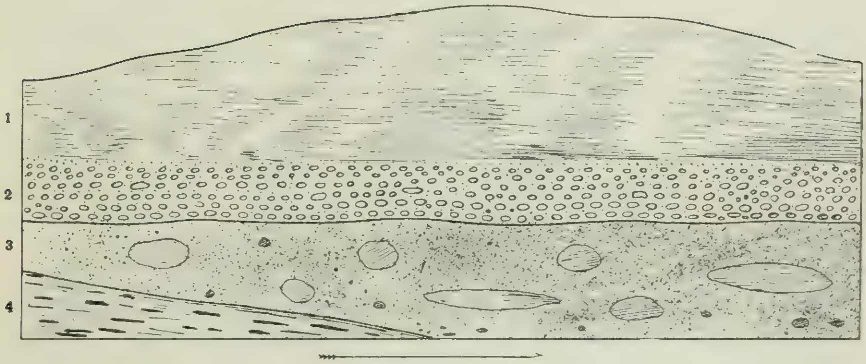

Fig. 1.—Dutch Gap Canal. Diagrammatic representation of the east bank.

IV. *Section on Dutch Gap Canal.*

		Feet
Pleistocene	1. Argillaceous sand grading down into gravel	20
	2. Cobble bed	5
Lower Cretaceous. Patuxent	3. Coarse, arkosic gray sand with numerous pebbles, clay pellets, and clay balls. The latter are barren dark drab clay or hard brown clay or somewhat sandy brown clay with leaf impressions. Occasional lenses of sandy brown clay, indistinctly laminated carry good leaf impressions including *Acrostichopteris parvifolia* Font. *Acrostichopteris pluripartita* (Font.) Berry, *Arthrotaxopsis grandis* Font., *Cladophlebis oblongifolia Font.*, *Cladophlebis distans* Font., *Cladophlebis Browniana* (Dunk.) Seward, *Dioonites Buchianus* (Ett.) Born., *Dryopteris dentatum* Font., *Dryopteris macrocarpum* Font., *Leptostrubus foliosus* Font., *Nageiopsis longifolia* Font., *Nageiopsis zamioides.* Font., *Onychiopsis Goepperti* (Schenk) Berry, *Osmunda sphenopteroides* Font *Scleropteris elliptica* Font., *Sequoia Reichenbachi* (Gein) Heer, *Sphenolepis Kurriana* Schenk, *Thyrsopteris brevifolia* Font., *Thyrsopteris brevipennis* Font., *Thyrsopteris dentata* Font., *Thyrsopteris divaricata* Font., *Thyrsopteris obtusiloba* Font., and *Zamites tenuinervis* Font........	0-9
	4. Dark drab stratified, pyritiferous and lignitic clays	0-6
	Total...............................	26-3

Above the lower entrance to the canal along the right bank of the old river channel the Potomac Group is exposed more or less continuously for a distance of between 3 and 4 miles as far as the Howlett House bluff. At this point the following section is seen:

V. *Section at Howlett House Bluff.*

		Feet
Pleistocene. Sunderland	Yellowish sandy loam..................about	45
Miocene. Calvert	Fine yellow sand clay..................about	35
Eocene. Aquia	Glauconitic argillaceous sand becoming indurated below..............................	15
Lower Cretaceous. Patuxent	Coarse gravelly sand	10
	Cross-bedded, arkosic sand..................	18
	Similar materials with cobbles. Indurated in places	2
	Total..............................	125

Between this point and the lower entrance to the canal clay lenses of very limited extent, and clay balls, have furnished the following fossil plants:

Acrostichopteris parvifolia Font.
Acrostichopteris pluripartita (Font.) Berry
Araucaria obtusifolia Font.
Araucarites virginious Font.
Brachyphyllum crassicaule Font.
Cladophlebis Albertsii (Dunk.) Brongn.
Cladophlebis Browniana (Dunk.) Seward.
Cladophlebis Ungeri (Dunk.) Ward
Dioonites Buchianus (Ett.) Born.
Frenelopsis parceramosa Font.
Onychiopsis Goepperti (Schenck) Berry
Ruffordia Goepperti (Dunk.) Seward.
Sphenolepis Kurriana (Dunk.) Schenk
Thyrsopteris angustifolia Font.
Thyrsopteris angustiloba Font.
Thyrsopteris rarinervis Font.
Williamsonia virginiensis Font.

The next and last exposure of Potomac Group on the James River is at Deep Bottom, 4 miles below Dutch Gap on the left bank just below Three Mile Creek. At this point the following section is seen in the ravine of the creek.

VI. *Section at Deep Bottom.*

		Feet
Pleistocene	Argillaceous sand and loam..................	10-20
	Gravel bed	5-10
Eocene	Glauconitic argillaceous sand................	4-5
Lower Cretaceous. Patapsco	Exposed about............................	3
	Arkosic sand with cobbles above and containing lenses and balls of sandy brownish clay carrying leaf impressions including *Araliaephyllum crassinerve* (Font.) Berry, *Cladophlebis constricta* Font., *Ficophyllum crassinerve* Font., *Juglandiphyllum integrifolium* Font., *Nageiopsis longifolia* Font., *Podozamites acutifolius* Font., *Populophyllum crassinerve* Font., *Sapindopsis magnifolia* Font., *Sassafras bilobata* Font., *Sphenopteris latiloba* Font., *Sterculia elegans* Font., *Thyrsopteris brevipennis* Font., and *Ulmiphyllum crassinerve* Font............................	
	Total..............................	22-38

While the lithology of the Potomac portion of this exposure is not to be differentiated from that of the preceding sections the fossils indicate that it represents a remnant of the Patapsco formation, the most southerly one known, as well as the only recognizable exposure of this age on the James River, marking the point where the Potomac dissappears beneath tide.

APPOMATTOX RIVER SECTIONS.[a]

No satisfactory exposures of Potomac strata occur at Petersburg although low exposures of Patuxent arkosic sand are to be seen in various road cuttings in the vicinity of the town. The river banks are low for some miles below, the only notable Potomac section on the river being that at Point of Rocks, although the Patuxent is exposed more or less along the right bank for some 3½ miles above the Point. The banks are much slipped and poorly exposed and furnish nothing worthy of comment except occasional traces of plant fossils, none of which are complete enough for accurate identification.

At Point of Rocks, which is on the left bank about 4 miles above City Point, the only good section on the river shows the following details:

I. *Section at Point of Rocks.*

		Feet
Pleistocene	Argillaceous sand with gravel bed containing cobbles along the base	5-12
Lower Cretaceous. Patuxent	Lenticularly cross-bedded coarse arkosic sand with scattered cobbles in places, firmly and extensively indurated	75-80
	Total	92

The minor details of this section are very variable, no two points along the bluff showing exactly the same succession.

Below Point of Rocks the left bank of the Appomattox is low and shows no exposures while along the right bank for a distance of about two miles occasional poor exposures of Potomac materials rise from 10 to 20 feet above tide and are overlain with Eocene or Pleistocene. One of these about one and a fourth miles below Point of Rocks shows the following section:

[a] The writer had the benefit of Mr. Arthur Bibbins notes of the Appomattox River section.

II. *Section below Point of Rocks.*

		Feet
Pleistocene	Argillaceous loam with gravel at base........	10
Eocene. Aquia	Weathered glauconitic argillaceous sand exposed	12
	Concealed	6
Lower Cretaceous. Patuxent	Arkosic sand with scattered pebbles..........	16
	Total................................	34

The last exposures of the Potomac Group on the Appomattox River are about three miles above City Point at a locality known as Figs Wharf where from 10 to 15 feet of coarse arkosic sand apparently of Patuxent age is overlain with from 10 to 20 feet of Aquia greensand.

SECTIONS ALONG THE RICHMOND, FREDERICKSBURG AND POTOMAC RAILROAD.

A large number of sections showing Potomac outcrops are to be seen along the line of the R. F. & P. R. R. between Alexandria and Fredericksburg of which the following are the more representative:

I. *Section in cut one-half mile north of Accotink.*

		Feet
Pleistocene	Ferruginous sand and gravel..................	10
Lower Cretaceous. Patuxent	Cross-bedded arkosic gray sands more or less lithified with occasional balls of greenish hackly clay..............................	40
	Total................................	50

II. *Section in cut just north of Accotink.*

		Feet
Pleistocene	Ferruginous gravel with boulders............	2-5
Lower Cretaceous. Patuxent	Brownish sandy clay with plant fragments....	0-6
	Cross-bedded coarse gray arkosic sand........	5
	Very sandy brownish clay....................	2-3
	Total................................	9-19

III. *Section in second cut south of Accotink.*

		Feet
Pleistocene	Sand and gravel with cobbles and boulders up to 3 feet in diameter.....................	2-10
Lower Cretaceous. Patuxent	Coarse arkosic cross-bedded sands with clay pellets	10-15
	Iron crusts................................	6 ins.
	Greenish black clay.........................	4-6
	Total................................	17-31

The Patuxent surface is very uneven and angular. Supposed Lafayette cobbles and boulders fill the erosion pockets.

IV. *Section in cut just north of Pohick.*

			Feet
Pleistocene		Ferruginous gravel	5-6
Lower Cretaceous.	Patuxent	Coarse cross-bedded gray arkosic pebbly sand	10-15
		Total	15-21

V. *Section in cut south of Pohick.*

			Feet
Pleistocene		Brownish sand with gravel and cobbles	10-15
Lower Cretaceous.	Patuxent	Lithified gray cross-bedded arkosic sand with thin lenses of drab clay	10
		Total	20-25

VI. *Section in cut one-quarter mile south of Lorton.*

			Feet
Pleistocene		Coarse buff sand and gravel with occasional cobbles	4-5
Lower Cretaceous.	Patuxent	Coarse gray arkosic cross-bedded sand	10
		Laminae, pellets and balls of drab clay with leaf impressions, including *Brachyphyllum parceramosum* Font., *Dioonites Buchianus* (Ett.) Born., *Nageiopsis angustifolia* Font., *Nageiopsis longifolia* Font., *Podozamites acutifolius* Font., *Podozamites distantinervis* Font., *Sequoia ambigua* Heer, *Sphenolepidium Kurrianum* (Dunk.) Heer, *Sphenolepidium Sternbergianum* (Dunk.) Heer, *Scleropteris elliptica* Font., *Zamites tenuinervis* Font., etc.	2
		Greenish sandy clay	0-5
		Total	16-22

The next important cut is that just south of Freestone which is given in the Potomac River sections.

VII. *Section in cut south of Powells Creek.*

			Feet
Pleistocene		Ferruginous sand and gravel	2-5
Eocene.	Aquia	Argillaceous glauconitic sands	10-20
Lower Cretaceous.	Patapsco	Sandy, arkosic, cross-bedded sand with scattered pebbles, clay pellets, and some large clay balls	30-50
		Total	42-75

The next section near Cherry Hill shows similar Patuxent materials rising for some 30 feet above the track directly overlain by 10 feet of surficial deposits, the Aquia being cut out.

From this point to Aquia Creek no good outcrops of Potomac materials are exposed although low exposures of the usual arkosic sands are seen at intervals overlain by Eocene or Pleistôcene materials.

VIII. *Section in first cut south of Aquia Creek.*

		Feet
Pleistocene	Sandy loam and soil	6
Eocene. Aquia	Glauconitic sand, sparingly fossiliferous	15
Lower Cretaceous. Patapsco	Coarse cross-bedded gray sand with iron crusts	15
	Greenish and drab arenaceous leaf-bearing clays with *Acrostichopteris longipennis* Font., *Nelumbites tenuinervis* (Font.) Berry, *Populophyllum reniforme* Font., *Sapindopsis brevifolia* Font., *magnifolia* Font., and *variabilis* Font., *Sphenolepidium sternbergianum* (Dunk.) Heer, etc	20
	Coarse cross-bedded arkosic sand with pebbles and clay pellets	18
	Lighter more argillaceous arkosic materials exposed to R. R. track	15
	Total	89

The track is about 20 feet above tide, and up the creek a short distance variegated Patapsco clays are visible near the water's edge.

IX. *Section at 72-mile Post.*

		Feet
Pleistocene	Pebbly soil grading down into coarse reddish argillaceous sand with pebbles and clay pellets	5
	Unconformity	
Eocene. Aquia	Glauconitic argillaceous sands	20-25
Lower Cretaceous. Patapsco	Argillaceous sand with local cobbles up to 5 inches in diameter	1
	Brown sandy clay with leaf impressions	1-2
	Drab argillaceous sand	1-2
	Coarse, arkosic, gray, argillaceous ferruginous cross-bedded sand, carrying pebbles	6-8
	Total	43

The plant remains from this locality include the following, about half of which are Dicotyledonæ:

Araliaephyllum magnifolium Font.
Araliaephyllum crassinerve (Font.)
Aristolochaephyllum crassinerve Font.
Arthrotaxopsis grandis Font.
Brachyphyllum crassicaule Font.
Celastrophyllum acutidens Font.
Celastrophyllum parvifolium (Font.) Berry
Cladophlebis Browniana (Dunk.) Seward.
Cladophlebis crenata Font.
Cladophlebis constricta Font.
Dryopteris virginica Font.
Hederaephyllum dentatum (Font.) Berry
Myrica brookensis Font.
Myricaephyllum dentatum Font.
Nageiopsis angustifolia Font.
Nageiopsis longifolia Font.
Nelumbites virginiensis (Font.) Berry
Onychiopsis Goepperti (Schenk) Berry
Onychiopsis psilotoides (Stokes and Webb) Ward
Populophyllum grossedentatum Font.
Sapindopsis brevifolia Font.
Sapindopsis magnifolia Font.
Sapindopsis variabilis Font.
Sassafras bilobata Font.
Sassafras parvifolium Font.
Dichotozamites cycadopsis Font.
Sphenolepis Kurriana (Dunk.) Schenk
Sphenolepis Sternbergiana (Dunk.) Schenk
Thinnfeldia Fontainei Berry
Torreya virginica Font.
Ulmophyllum brookense Font.
Widdringtonites ramosus (Font.) Berry

X. *Section near Brooke.*

			Feet
Eocene.	Aquia	Argillaceous glauconitic sand...........about	40
Lower Cretaceous.	Patapsco	Light gray massive arkosic coarse sand with pebbles, clay balls and clay lenses with leaf impressions indurated in the lower part .... about	20
		Total..........................about	60

The plant remains from near Brooke include:

Acrostichopteris longipennis Font.
Acrostichopteris pluripartita (Font.) Berry
Araucarites aquiensis Font.
Carpolithus brookensis Font.
Cladophlebis Browniana (Dunk.) Seward
Dryopteris ellipticum Font.
Dryopteris pinnatifidum Font.
Nageiopsis angustifolia Font.
Nelumbites virginiensis (Font.) Berry
Podozamites acutifolius Font.
Sapindopsis brevifolia Font.
Sapindopsis magnifolia Font.
Sapindopsis variabilis Font.
Sphenolepis Kurriana (Dunk.) Schenk

The following table shows the geographical distribution in the Virginia area of the various members of the Potomac flora.

TABLE SHOWING THE DISTRIBUTION OF THE POTOMAC FLORA.

	Patuxent Formation.												Patapsco Formation									
	Colchester Road.	Lorton (Telegraph) Station.	Cockpit Point.	Potomac Run.	Kankeys.	Woodbridge.	Fredericksburg.	Alum Rock.	Dutch Gap.	Trents Reach.	Nealsco Creek.	Chinkapin Hollow (Lower).	Chinkapin Hollow (Upper).	Mt. Vernon.	White House Bluff.	Hell Hole.	Dumfries Landing.	Widewater.	Aquia Creek.	Brooke.	72 mile post.	Deep Bottom.
Filicales.																						
Schizaeopsis americana							*		*	*												
Ruffordia acrodentata									*													
Ruffordia Goepperti							*		*	*												
Acrostichoptertis cyclopteroides									*													
Acrostichopteris adiantifolia		*		*			*					*										
Acrostichopteris parvifolia				*			*		*	*												
Acrostichopteris pluripartita		*					*		*	*						*				*	*	
Acrostichopteris longipennis														*	*	*	*	*	*	*	*	
Cladophlebis Browniana		*		*			*	*	*			*								*		
Cladophlebis constricta							*									?				*		*
Cladophlebis rotundata							*		*			*		*								
Cladophlebis virginiensis				*			*		*			*										
Cladophlebis parva			*	*			*															
Cladophlebis Albertsii		*		*			*		*	*												
Cladophlebis Ungeri		*				*	*		*			*										
Cladophlebis distans		*					*		*			*										
Dryopteris macrocarpa									*													
Dryopteris pinnatifida																				*		
Dryopteris cystopteroides							*															
Dryopteris elliptica				*																*		
Dryopteris dentata		*		*					*													
Dryopteris virginica							*													?		
Aspleniopteris pinnatifida							*															
Aspleniopteris adiantifolia							*															
Onychcopsis latiloba		*					*		*					*		?	?					
Onychcopsis psilotoides				*			*		*	*						*		*		*		
Onychcopsis brevifolia		*		*			*		*													
Onycheopsis Goepperti	*		*	*			*		*	*		*		*	*		*			*		
Onychcopsis nervosa				*			*		*			*										
Sagenopteris latifolia		*																				
Sagenopteris elliptica				*	*																	
Sagenopteris virginiensis							*															
Taeniopteris auriculata				*			*															
Taeniopteris nervosa		*		*			*															
Scleropteris elliptica		*	?	*	*		*		*			*										
Thinnfeldia fontainei				*											*					*		
Thinnfeldia granulata		*		*						*												
Thinnfeldia rotundiloba				*			*															
Gleichenia nordenskioldi									*													
Osmunda dicksonioides				*																		
Osmunda sphenopteroides									*													
Polypodium dentatum							*															
Polypodium fadyenioides				*																		
Sphenopteris grevilloides														*	*							
Equisetales.																						
Equisetum Lyelli							*		*													
Equisetum Burchardti		*	*						*													
Cycadophyta.																						
Dioonites Buchianus		*	*		*				*	*												
Ctenopteris insignis				*			*															
Ctenopteris angustifolia				*								*										
Ctenopteris longifolia							*															
Ctenopsis latifolia							*															
Zamiopsis dentata							*															

TABLE SHOWING THE DISTRIBUTION OF THE POTOMAC FLORA.

	Patuxent Formation.												Patapsco Formation.									
	Colchester Road.	Lorton (Telegraph) Station.	Cockpit Point.	Potomac Run.	Kankeys.	Woodbridge.	Fredericksburg.	Alum Rock.	Dutch Gap.	Trents Reach.	Neabsco Creek.	Chinkapin Hollow (Lower).	Chinkapin Hollow (Upper).	Mt. Vernon.	White House Bluff.	Hell Hole.	Dumfries Landing.	Widewater.	Aquia Creek.	Brooke.	72 mile post.	Deep Bottom.
Zamiopsis petiolata							*															
Zamiopsis laciniata							*															
Nilsonia Rogersi												*										
Nilsonia densinerve							*															
Zamites tenuinervis					*		*		*					*			*	*				
Zamites crassinervis				*	*		*		*													
Dichotozamites cycadopsis														*						*		
Cycadeospermum acutum				*				*														
Cycadeospermum rotundatum					*																	
Cycadeospermum spatulatum				*			*		*													
Podozamites grandifolius				*			*															
Podozamites subfalcatus		*																		*	*	
Podozamites acutifolius		*							*											*		*
Podozamites inaequilateralis			*	*	*																	
Podozamites distantinervis				*			*		?													
Podozamites knowltoni														*								
Podozamites lanceolatus		*																				
Williamsonia virginiensis									*	*												
Ctenis imbricta							*															
GYMNOSPERMAE.																						
Baiera foliosa									*													
Nageiopsis longifolia		*	*	*	*		*		*				?	*						*		?
Nageiopsis angustifolia				*			*		*					*						*		
Nageiopsis zamiodes			*	*			*		*			*										
Cephalotaxopsis magnifolia				*			*		*													
Cephalotaxopsis brevifolia				*			*		*													
Brachyphyllum crassicaule									*	*							*	*		*		
Brachphyllum parceramosum		*																				
Araucarites aquiensis													*	*				*	*	*		
Araucarites patapscoensis																		*				
Abietites macrocarpus							*		*													
Abietites longifolius				*			*		*					*		*				*	*	
Abietites foliosus									*													
Pinus vernonensis														*				*				
Cupressinoxylon columbianum									*													
Cupressinoxylon Wardi											*											
Frenelopsis ramosissima							*					*				?						
Frenelopsis parceramosa										*												
Sphenolepis Kurriana		*	*	*	*		*		*	*				*		*						
Sphenolepis Sternbergiana		*	*	*		*	*	*					*	*	*	*	*	*	*	*	*	
Laricopsis angustifolia									*	*												
Arthrotaxopsis expansa		*	*	*			*		*													
Arthrotaxopsis grandis							*		*													
Widdringtonites ramosus														*	*	*				*	*	
Sequoia Reichenbachi		*					*		*											*		
Sequoia rigida		*		*																		
Sequoia delicatula									*													
Sequoia ambigua		*	*	*			*		*													
Tumion falcatum				*																		
Tumion virginicum																				*		
Phyllocladopsis heterophlla									*													
Leptostrobus ? multiflorus																				*		
Feistmantelia virginica			*																			
Feildeniopsis crassinervis					*																	
Ephedrites ? vernonensis														*								
Araucaria obtusifolia										*												
Araucaria podocarpoides																				*		
Araucaria zamioides				*																		

TABLE SHOWING THE DISTRIBUTION OF THE POTOMAC FLORA.

	Patuxent Formation.												Patapsco Formation.									
	Colchester Road.	Lorton (Telegraph) Station.	Cockpit Point.	Potomac Run.	Kankeys.	Woodbridge.	Fredericksburg.	Alum Rock.	Dutch Gap.	Trents Reach.	Neabsco Creek.	Chinkapin Hollow (Lower).	Chinkapin Hollow (Upper).	Mt. Vernon.	White House Bluff.	Hell Hole.	Dumfries Landing.	Widewater.	Aquia Creek.	Brooke.	72 mile post.	Deep Bottom.
Angiospermae.																						
Alismaphyllum Victor Masoni														*								
Populus potomacensis														*	*							
Populophyllum minutum														*								
Populophyllum reniforme														*	*			*	*		*	
Nelumbites virginiensis														*		*				*	*	
Nelumbites tenuinervis														*	*				*			
Sapindopsis variabilis														*	*			*	*	*	*	
Sapindopsis magnifolia															*			*	*	*	*	?
Sapindopsis brevifolia																			*	*	*	
Celastrophyllum parvifolium																*					*	
Celastrophyllum acutidens													*		*			*			*	
Sassafras bilobatum																?				*		
Sassafras parvifolium																				*		
Sassafras potomacensis																	*	*				
Araliaephyllum crassinerve																				*		*
Araliaephyllum magnifolium																				*	*	
Hederaephyllum dentatum																				*		
Ficophyllum serratum							*															
Ficophyllum oblongifolium				*			*		*													
Proteaephyllum reniforme							*		*													
Proteaephyllum ovatum				*			*		*													
Rogersia longifolia					*		*		*													
Rogersia angustifolia				*			*															
Aristolochiaephyllum crassinerve																*				*	*	
Aristolochiaephyllum ? cellulare														*								
Menispermites potomacensis																		*				
Antholithus gaudium-rosae														*								
Aralia ? vernonensis														*								
Casuarina covillei														*								
Hymenaea virginiensis																				*		
Potamogetophyllum vernonense														*								
Quercophyllum grossedentatum																				*		
Sterculia elegans														*								*
Ulmophyllum brookense																				*		*

UPPER CRETACEOUS.

In New Jersey deposits of Upper Cretaceous age are extensively developed and appear at the surface over a wide belt which crosses the entire State from northeast to southwest. Below the Delaware River in Delaware and Maryland the width of this belt gradually decreases through the overlapping of the Eocene beds and in the region of the Potomac River the deposits disappear entirely and have not as yet been found at the surface anywhere in Virginia. That Upper Cretaceous deposits form a part of the Coastal Plain of this State, however, is certain as at least five deep-well borings in the vicinity of Norfolk and one at Fairport in Northumberland County have revealed their presence between the Eocene and Potomac deposits. Darton[a] estimates the total thickness of these beds to be at least 65 feet and possibly considerably more. The materials consist of greensand, micaceous sand, dark sandy lignitic clay, stiff clay, fine sand, coarse gray sand, pebbles, and shells.

The Upper Cretaceous age of the deposits is determined by the fossils which have been brought to the surface. In the Norfolk Water Works well an *Exogyra* somewhat resembling *Exogyra ponderosa* was very abundant in the materials penetrated between the depths of 700 and 775 feet. In the well at Lambert Point, Norfolk, a bed between 563 and 610 feet yielded the following forms: *Exogyra ponderosa, Astarte octolirata, Ostrea plumosa, Gouldia* (?) *decemnaria, Gryphea vesicularis, Liopistha* (*Cymella*) *bella, Corbula* sp., *Modiolus* sp., and *Baculites* (?). In the well at the Chamberlain Hotel, Old Point Comfort, fragments of *Terebratula harlani* (?) were obtained.

In New Jersey the Upper Cretaceous is divided from below upward into the Raritan, Magothy, Matawan, Monmouth, Rancocas, and Manasquan formations, each characterized by distinct lithological and faunal features. The data obtained from the few deep-well sections about Norfolk and Fairport are too meagre to determine definitely just what formations are present but it seems probable that more than one horizon is represented in this part of Virginia. The dark sandy micaceous clays penetrated in the Norfolk Water Works well and in the Chamberlain Hotel well resemble the materials which compose so large a proportion of the Matawan formation in Maryland and New Jersey and the fossils from the Lambert Point well are characteristic of that horizon.

In New Jersey the fossil *Terebratula harlani* has been found only in the Rancocas formation while the other fossils are characteristic of lower beds.

[a] Darton, N. H., U. S. Geol. Survey Folio, No. 80.

CENOZOIC

TERTIARY.

The Tertiary deposits of Virginia form part of a complex series of formations that extend interruptedly from New Jersey southward to the Gulf of Mexico. At no point in the region is the series more complete or better exposed than in the Chesapeake Bay drainage basin, the bluffs along the Maryland and Virginia streams having long been classic ground for the study of American Tertiary strata. These Tertiary beds overlie unconformably the Cretaceous deposits which they gradually transgress landward. The Tertiary of Virginia is represented by deposits of Eocene, Miocene, and Pliocene (?).

EOCENE.

THE PAMUNKEY GROUP.

The Eocene strata of the Middle Atlantic Coastal Plain form a belt of varying width, extending from northeast to southwest, somewhat to the west of the center of the Coastal Plain. This belt has been traced almost continuously from the Maryland-Delaware line to the valley of the Nottoway River in southern Virginia. Although in places buried beneath later deposits, fine exposures of Eocene strata occur along all the leading stream-channels, while not infrequently broad outcrops of the beds appear at the surface in the intervening country.

The Eocene deposits overlie the Cretaceous formations unconformably and consist largely of greensand marls which may, however, by weathering, lose their characteristic green color, and by the deposition of a greater or less amount of hydrous iron oxide become firm, red or brown sandstones or incoherent red sands. In certain places, notably in southern Maryland and Virginia, the strata become highly argillaceous, the glauconitic elements largely or entirely disappearing. Infrequently coarse sands and even gravels are found, the latter chiefly toward the base of the deposits and near the ancient shore-line. Very commonly the shells of organisms are so numerous as to form the chief constituent of certain beds, which occasionally become cemented by calcium carbonate to form impure limestones.

Notwithstanding the fact that several different kinds of materials are found composing the Eocene beds, the deposits on the whole are remarkably

homogeneous. There is seldom any difficulty experienced in drawing the line of separation between the Eocene strata and the overlying and underlying formations. The great amount of glauconite in the Eocene deposits and the homogeneity of the deposits as a whole, at once separate them from the extremely variable and highly colored sands and clays of the Potomac formations below, and from the blue clays, light colored sands, and diatomaceous earth beds of the overlying Miocene.

Even though the Eocene deposits have characters so persistent that they can readily be separated from adjacent formations, yet recent investigations have shown the possibility of dividing the deposits into two well-marked formations on both lithologic and faunal grounds. These formations have received the names of Aquia and Nanjemoy. The Eocene deposits of Maryland and Virginia were first supposed to constitute a single stratigraphic unit which was called the Pamunkey formation. Since the division of the deposits into two formations the term Pamunkey is retained as a group name. The lower or Aquia formation is much more highly arenaceous than the upper or Nanjemoy formation which, particularly in its lower part, is generally highly argillaceous. The Aquia formation is also much more calcareous than the Nanjemoy formation, indurated layers frequently appearing in the former. Both formations are, however, highly glauconitic.

The most complete section of the Eocene strata in the Middle Atlantic Slope is afforded by the series of high bluffs on the western bank of the Potomac River between Aquia Creek and Mathias Point, in eastern Stafford and King George counties. The peninsula between the Potomac and Rappahannock rivers is to a large extent formed of the Eocene greensands, which also appear along the banks of the latter stream, outcropping beneath the Columbia formations. The higher levels of the intervening country are, however, generally capped by the Miocene and Columbia formations.

The Eocene deposits are continued southward in Spottsylvania and Caroline counties. Fine bluffs of the characteristic marls appear on the south bank of the Rappahannock at several points above Port Royal, but in the valley of the Mattaponi they are much less prominent although occurring at frequent intervals. An extensive cover of later deposits occupies the higher portions of the country. In the valley of the Pamunkey River and its tributaries, particularly in Hanover County, important outcrops of Eocene strata are found. For this reason the name Pamunkey was first selected as the name for the formation. Many of the fossils described by Conrad and Rogers were obtained along the Pamunkey River.

Farther south, in the valley of the James River, there are many excellent outcrops of Eocene material exposed at intervals from Richmond to a short

distance below City Point, while there are some exposures along the lower course of the Appomattox River. South of the Appomattox the only exposures thus far known are in the vicinity of Bollings Bridge, on the Nottoway River.

The Aquia Formation.

Name.—The formation receives its name from Aquia Creek, a stream which empties into the Potomac River in Stafford County. Along the lower course of this stream as well as along the banks of the Potomac River near its mouth are found several fine exposures. The name was proposed by W. B. Clark[a] in 1895, and further defined in 1896[b].

Stratigraphic relations.—The Aquia formation rests unconformably upon the irregularly eroded surface of the Potomac formations. In the northern portion of the State it overlies the Patapsco, while in the James River basin it rests upon the exceedingly uneven surface of the Patuxent formation. In the latter locality the most marked unconformities thus far recognized in the Virginia Coastal Plain are found. Thus along Shockoe and Gillis creeks in Richmond and along the tributaries of the Appomattox River a few miles north of Petersburg the Aquia is exposed only a little above tide, while along the strike of these exposures and even to the east of them at Drewry's Bluff, Howlett House Bluff, the high bluff above the Dutch Gap canal, on the James River, and at Point of Rocks on the Appomattox River the Patuxent is found rising from 40 to 80 feet above tide. At Point of Rocks the Patuxent would be expected to occur at from 25 to 30 feet below tide, as the Aquia deposits at Ashton Creek, two miles directly west, are almost at tide, but instead of this the Patuxent rises about 80 feet above tide. No faulting has apparently occurred. Thus in the distance of about two miles there is an apparent unconformity amounting to about 100 feet. The Aquia is conformably overlain by the Nanjemoy formation or unconformably by the unconsolidated deposits of the Pleistocene where the Nanjemoy is wanting.

Lithologic character.—The Aquia formation consists primarily of greensands and greensand marls interbedded with which are occasionally layers composed almost entirely of shells. The latter often become thoroughly indurated. Such beds are excellently exposed near the mouth of Aquia Creek and near the tops of the divides east of Stafford. The greensand on weathering frequently becomes reddish-gray, yellow, or reddish-brown in

[a] Johns Hopkins Univ. circ., vol. xv, 1895, pp. 3.
[b] Bull. U. S. Geol. Survey, No. 141, p. 39.

color. Argillaceous beds occur but there is much less clay in the Aquia than in the Nanjemoy formation. The greater portion of the strata constituting the Aquia formation seems to have been accumulated in quiet and probably relatively deep water, as the bedding planes are very regular and the materials are largely fine sand. While the basal beds of the Aquia were being formed the water was probably shallower and the shore-line closer, as we find in these beds some small pebble bands which are absent in the higher beds. The general character of the formation is shown in the detailed sections given on a subsequent page.

Strike, dip, and thickness.—The strike of the Aquia formation is almost due north and south and the beds dip to the east at the rate of from 12 to 15 feet to the mile. This dip has been determined from surface exposures in the region of outcrop in Stafford County and probably continues at about the same rate after it passes at tide beneath the overlying formations as the base of the Eocene is found at a depth of 840 feet in the new government well at Fortress Monroe.

The thickness of the Aquia formation in Stafford County is about 100 feet, and this thickness is probably rather constant throughout the Coastal Plain. In the Fortress Monroe well just mentioned the total thickness of the Eocene is only a little in excess of 200 feet and if half of that thickness represents the Aquia, as seems probable, the formation will be seen to maintain about the same thickness even down the dip.

Divisions.—The Aquia formation has been divided into two members known as the *Piscataway* indurated marl and *Paspotansa* greensand marl, each having a thickness of about 50 feet. The Piscataway member is characterized by greensands and greensand marls, the lower beds often very argillaceous. The well-marked and rather persistent layers of indurated marl characterizes the upper beds in the Potomac region. The Paspotansa member is composed of a thick bed of greensand, overlain by thick-bedded, indurated layers of greensand marl. The Piscataway member in the Potomac region is again divided into seven zones and the Paspotansa member into two zones. The two members show paleontological differences to which reference will be made later.

Paleontological character.—The Aquia formation has yielded a great many fossils belonging to most of the groups of the invertebrates as well as to the fishes and reptiles among the vertebrates. The mollusks, especially the Pelecypoda and Gastropoda, are represented by countless individuals and by many species. All are marine forms. Many of the Aquia species are limited to this formation although a considerable number survived during the deposition of the Nanjemoy.

Among the forms which are restricted to the Aquia formation but found in both its members are:

Turritella mortoni Conrad
Turritella humerosa Conrad
Scala virginiana Clark
Gibbula glandula (Conrad)
Panopea elongata Conrad
Meretrix ovata var. *pyga* (Conrad)
Dosiniopsis lenticularis (Rogers)
Lucina aquiana Clark
Venericardia planicosta var. *regia* Conrad
Crassatellites alaeformis Conrad
Crassatellites aquiana Clark
Ostrea compressirostra Say
Leda cliftonensis Clark and Martin
Trochocyathus clarkeanus Vaughan
Eupsammia elaborata (Conrad)

The following species among others have been found only in the Piscataway member:

Trionyx virginiana Clark
Synechodus clarkii Eastman
Odontaspis elegans (Agassiz)
Phenacomya petrosa (Conrad)
Pholadomya marylandica Conrad
Lithophaga marylandica Clark and Martin
Ostrea compressirostra var. *alepidota* Dall

The following species among others have been found only in the Paspotansa member:

Pleurotoma harrisi Clark
Pleurotoma potomacensis Clark and Martin
Cancellaria potomacensis Clark and Martin
Mitra pomonkensis Clark and Martin
Tudicla marylandica Clark and Martin
Calyptraphorus jacksoni Clark
Aporrhais potomacensis Clark and Martin
Diplodonta marlboroensis Clark and Martin
Crassatellites alta (Conrad)
Platidia marylandica Clark and Martin
Paracyathus marylandicus Vaughan
Balanophyllia desmophyllum Milne Edwards and Haime.

Areal distribution.—The Aquia formation outcrops along all the important streams and many of their tributaries in a narrow belt extending from the Potomac River to the James River and passing through the counties of Stafford, King George, Caroline, Hanover, Henrico, Chesterfield, and Prince George with one isolated locality along the Nottoway River in Sussex County. The base of the formation rises above tide on Aquia Creek about one-half mile east of the railroad crossing, about the same distance east of the railroad on Potomac Creek, about 7 miles below Fredericksburg on the Rappahannock, near the mouth of Massaponax Creek and at Deep Bottom on the James River. From these places the formation gradually rises toward the west, appearing at higher and higher levels along the valley slopes until it reaches to the height of the stream divides, where it is either exposed or covered with a thin capping of Lafayette or Columbia materials. The line of separation between the Aquia and Nanjemoy has only been determined in a few places because of the lack of suitable exposures. Along

the Potomac River the Aquia appears above tide from beneath the Nanjemoy deposits about 4 miles below the mouth of Potomac Creek. The line of contact can be followed to the west to the top of the divides between the Potomac and Rappahannock rivers a short distance to the east of the R. F. and P. R. R. The Aquia formation is also excellently exposed in numerous places along nearly all the minor streams to the east of the railroad in Stafford County and in many places along the lower courses of the leading streams in northeastern Spottsylvania, northwestern Caroline, and western King George counties. Along the James River the Aquia formation appears in Richmond along Shockoe Creek beneath the clay and diatomaceous earth deposits of the Calvert formation, and is similarly exposed in the valleys of Gillis and Almond creeks. Probably the Eocene deposits exposed along the Nottoway River in Sussex County also belong to the Aquia formation.

DETAILED SECTIONS.

SECTIONS IN POTOMAC RIVER VALLEY.

The Aquia formation is best exposed in the valley of the Potomac River and its tributaries. Exposures can be traced from the high lands bordering the District of Columbia southeastward until the formation reaches tide along the Maryland bank of the Potomac River in Charles County and on Aquia Creek in Stafford County, Virginia. Several sections from the Maryland bank of the Potomac are given in order to show the relations and detailed stratigraphy of the formation.

I. *Section at Glymont, north of wharf and ravine.*

				Feet
Pleistocene			Gravel and loam	20
Eocene.	Aquia	Piscataway	Light green glauconitic sand, underlain by argillaceous sand, with few fossils (Zone 4)	10
			Indurated greensand (Zone 3)	1
			Greenish marl with numerous fossils including *Ostrea compressirostra*, *Crassatellites alaeformis*, *Turritella mortoni*, *Dosiniopsis lenticularis*, *Meretrix ovata* var. *pyga*, *etc.* (Zone 2)	21
			Argillaceous glauconitic sand for the most part without fossils, but containing indeterminate plant remains and molluscan casts at the base (Zone 1)	8
Lower Cretaceous.	Patapsco		Variegated clays of the Potomac group	20
			Total	80

II. *Section two miles up Aquia Creek.*

				Feet
Pleistocene			Gravel and sand	7
Eocene.	Aquia	Piscataway	Indurated greensand (Zone 3)	1
			Greensand with characteristic fossils (Zone 2)	15
			Argillaceous sand more or less glauconitic without fossils (Zone 1)	18
			Total	41

III. *Section of western portion of bluff at Aquia Creek.*

				Feet
Pleistocene			Fine sand, light-yellow in color, with white clay near the base	26
Eocene.	Aquia	Paspotansa	Fine sand, of light-greenish color, containing a few glauconitic grains (Zone 10)	10
			Thick-bedded, arenaceous, and glauconitic limestone interstratified with unconsolidated layers of partially weathered greensand, the indurated layers largely filled with the shells of *Turritella mortoni* (Zone 9)	10
			Fine sand, of gray or green color, containing several irregular bands of *Turritella mortoni*, also *T. humerosa*, *Cucullaea gigantea*, *Crassatellites alaeformis* and *Ostrea compressirostra* (Zone 8)	30
			Dark-colored greensand chiefly filled with broken shells of *Meretrix ovata* var. *pyga* *Crassatellites alaeformis* (Zone 7)	7
		Piscataway	Ditto, with same shells in whole condition (Zone 6)	1
			Indurated layer of light-colored greensand filled with *Turritella mortoni*, *T. humerosa*, *Crassatellites alaeformis*, *Dosiniopsis lenticularis* *Meretrix ovata* var. *pyga*, *Panopea elongata*, *Pholadomya marylandica* (Zone 5)	2
			Greensand marl containing same forms (Zone 4)	8
			Indurated layer of dark-colored greensand with *Crassatellites alaeformis*, *Meretrix ovata* var. *pyga*, *Dosiniopsis lenticularis*, and *Ostrea compressirostra* (Zone 3)	2
			Greensand marl with *Dosiniopsis lenticularis*, *Meretrix ovata* var. *pyga* and *Crassatellites alaeformis* (Zone 2)	16
			Total	112

Fig. 1.—Base of bluff at mouth of Aquia Creek. Showing zones 2 and 4 of Aquia formation.

Fig. 2. Bluff near mouth of Aquia Creek. Showing blocks of indurated marl derived from zone 9 of Aquia formation, largely composed of shells of *Turritella mortoni*.

AQUIA FORMATION.

IV. *Section of center of bluff at Potomac Creek.*

				Feet
Pleistocene			Fine yellowish sand containing red and brown bands	15
Miocene			White gritty clay, with Miocene fossils at base	5
Eocene.	Nanjemoy	Potapaco	Greenish-gray argillaceous sand, slightly glauconitic (Zone 15)	38
			Argillaceous sand containing bands of selenite crystals (Zone 14)	4
			Light-gray glauconitic sand with *Venericardia potapacoensis* (Zone 13)	3
			Greenish-gray argillaceous sand (Zone 12)	8
			Indurated greensand with *Venericardia potapacoensis* (Zone 11)	1
			Greenish-gray argillaceous sand, glauconitic, with casts of *Meretrix* (Zone 10)	25
	Aquia	Paspotansa	Thick-bedded arenaceous and glauconitic limestone interstratified with layers of partially weathered greensand, the indurated strata largely composed of the shells of *Turritella mortoni* (Zone 9)	12
			Greensand bed, much weathered in its upper portions, and filled chiefly with *Turritella mortoni* in several thick layers; also *T. humerosa, Cucullaea gigantea, Crassatellites alaeformis, Ostrea compressirostra,* and many other species (Zone 8)	25
			Total	136

V. *Section on Potomac Run, near Potomac Church.*[a]

			Feet
Eocene.	Aquia	Very fine, loose, slightly argillaceous, yellow sand with imprints of shells sparingly shown	20
		Greenish-yellow and yellow, fine argillaceous sand, with many imprints of shells, especially in its lower portion forming a greensand marl	10
		Brownish-yellow sandy clay, spotted with white	4
		Dark gray clay, mottled with brown	5
		Gray argillaceous sand, with small pebbles	3
		Brownish sandy clay speckled and mottled with gray and white	3
		Thick mass, only partially exposed, of fine argillaceous and variegated incoherent sand	40
Lower Cretaceous.	Patapsco	Potomac cobblestone bed	3-4
		Friable reddish-brown sand	2½
		Dark-gray, coarse, somewhat argillaceous sand (exposed)	2-3
		Total	94½

[a]Bull. U. S. Geol. Survey, No. 145, p. 76.

VI. *Section one and one-half miles southeast of Stafford.*

				Feet
Eocene.	Aquia	Paspotansa	Indurated limestone containing principally casts of fossils although in some instances portions of the shell substance remain. *Turritella mortoni* is very numerous and appears to be of the same horizon as that exposed at the mouth of Aquia Creek....	12

SECTIONS ON THE RAPPAHANNOCK RIVER.

The Aquia formation is well exposed along the Rappahannock River from a short distance below Fredericksburg to Hopyard Wharf. Just below the latter point it dips below tide level, disappearing beneath the overlying Nanjemoy deposits.

I. *Section left bank of Rappahannock River, opposite mouth of Massaponax Creek.*

			Feet
Pleistocene		Sand, gravel, etc. ....about	12
Eocene.	Aquia	Gray argillaceous sand mottled with yellow probably weathered Eocene greensand....	5
Lower Cretaceous.	Patuxent	Coarse arkosic sand and gravel containing angular clay pebbles up to 3 inches in diameter	20
		Total..............................	37

II. *Section right bank of Rappahannock River, one-half mile below mouth of Massaponax Creek.*

			Feet
Pleistocene		Concealed except 2 feet of gravel along base	20
Eocene.	Aquia	Dark greensand not well exposed except 3 feet at base, sharp contact with underlying bed	22
Lower Cretaceous.	Patuxent	Coarse gravelly compact arkosic sand......	12
		Total..............................	54

III. *Section right bank of Rappahannock River, one mile below mouth of Massaponax Creek.*

		Feet
Pleistocene	Yellow sand and gravel with boulders......	8
Eocene. Aquia	Light greenish-gray glauconitic sand, probably dark green if not weathered........	17
	Similar materials full of fossils, *Crassatellites alaeformis, Cucullaea gigantea, Ostrea compressirostra, Meretrix ovata* var. *pyga, Turritella mortoni,* etc....................	12
	Dark green compact, finely micaceous greensand	15
	Total...............................	52

IV. *Section left bank of Rappahannock River, one and one-half miles below mouth of Massaponax Creek.*

		Feet
Pleistocene	Sand and gravel with boulders..............	8
Eocene. Aquia	Dark greensand ....about	20
	Total...............................	28

V. *Section right bank of Rappahannock River three miles below mouth of Massaponax Creek.*

		Feet
Pleistocene	Yellow sand and gravel ....about	10
Eocene. Aquia	Dark greensand more or less argillaceous, grading into clay at base. Fossil casts are present in lower 10 feet and especially abundant in lower 5 feet................	35
	Total...............................	45

VI. *Section a few hundred yards below preceding section.*

		Feet
Pleistocene	Coarse sand and gravel containing boulders	8
	Fine-grained greenish-gray carbonaceous sand	5
	Yellow gravel with pebbles up to 3 or 4 inches in diameter	5½
Eocene. Aquia	Dark green argillaceous finely micaceous sand	21
	(Irregular contact with offsets of as much as 2 feet suggest an unconformity but may be simply the irregular upper surface of marl lenses). Dark greensand full of fossils most of which are very fragile and soft, including *Ostrea compressirostra, Turritella mortoni, Meretrix ovata* var. *pyga* ?, *Crassatellites alaeformis, Modiolus alabamensis, Dosiniopsis lenticularis, Crassatellites sp*............................	13
	Total...............................	52½

VII. *Section left bank Rappahannock River, one mile above mouth of Muddy Creek.*

		Feet
Pleistocene	Yellow sand and gravel	22
Eocene. Aquia	Dark green argillaceous sand lighter in color where weathered. No fossils...........	40
	Total...............................	62

A half mile below the mouth of Muddy Creek, Aquia greensand is poorly exposed in the river bluff rising to a height of 10 feet above the water, while on the right bank of the river about 1½ miles below Muddy Creek light greenish-gray Aquia sand appears at the base of a 50-foot bluff. The greater portion of the bluff consists of Pleistocene sand and gravel.

VIII. *Section left bank of Rappahannock River one and one-quarter miles above the mouth of Ware Creek.*

		Feet
Pleistocene	Yellow sand and gravel with a line of large crystaline rock and quartz cobbles at base	28
	Greenish-gray, sandy clay and fine-grained stratified carbonaceous and argillaceous sand	14
	Band of coarse gravel with cobbles and boulders	2
Eocene. Aquia	Dark green, argillaceous sand with fossils principally ***Turritella mortoni;*** also ***Crassatellites alaeformis, Modiolus alabamensis, Meretrix ovata, Ostrea compressirostra, Lunatia marylandica, Corbula aldrichi, Diplodonta hopkinsensis, Crassatellites sp.***	2
	Total...............................46	

IX. *Section right bank of Rappahannock River just below mouth of Ware Creek.*

		Feet
Pleistocene	Not well exposed but principally composed of gravel and sand	20
Eocene. Aquia	Greenish-gray argillaceous sand. Fossils occur near the top of bed which is not well exposed. At the base there is a layer of shells containing numerous specimens of *Turritella mortoni.* Other species are the same as those in preceding section. Portions of this fossil layer are indurated....	15
	Total..............................	35

About one mile below the mouth of Ware Creek there is a 70-foot bluff on the right bank of the Rappahannock River apparently composed mainly of Aquia greensand.

X. *Section on Rappahannock River, Radcliffe's Wharf.*

		Feet
Pleistocene	Sand and gravel	14
Eocene. Aquia	Dark green argillaceous greensand. Fossils in lower 8 feet *Turritella mortoni, Crassatellites alaeformis, Meretrix ovata* (?), *Ostrea compressirostra, Lunatia marylandica, Modiolus alabamensis, Cucullaea gigantea* etc. *Turritella mortoni* is the most conspicuous fossil, being present in great numbers	17
	Total	31

Just above Hopyard Wharf the Aquia formation outcrops for a distance of half a mile or more. It consists mainly of a bluish sandy clay carrying some greensand. Near the base of the cliff in many places the material is indurated, to form nodules 6 to 10 feet long and 2 to 4 feet in diameter that lie flat and project from the bluffs. Both the blue clay and its nodules contain many casts and some shells of *Turritella mortoni.* Other forms are rare.

SECTIONS ALONG MATTAPONI RIVER.

Along the Mattaponi River in Caroline County the Aquia formation is exposed in a few places. It probably forms a continuous bed underlying the valley from a point about three miles north of Milford where there is a poor exposure of dark green glauconitic sand to a short distance below the crossing of the road which leads from Penola to Shumansville.

I. *Section right bank of Mattaponi River, R. F. & P. R. R. bridge, four miles south of Milford.*

		Feet
Pleistocene	Yellow sand and gravel	10
Eocene. Aquia	Dark colored greensand indurated in places to form large concretions and containing *Turritella mortoni* in large numbers with *Meretrix ovata, Modiolus alabamiensis, Crassatellites alaeformis, Ostrea compressirostra,* etc.	10
	Total	20

Between the point where the above section was taken and Milford, Aquia greensand containing fossil casts is poorly exposed in several places.

II. *Section right bank of Mattaponi River at first county bridge below R. F. & P. R. R. crossing.*

		Feet
Pleistocene	Concealed	8
Eocene. Aquia	Dark colored greensand with casts of *Turritella mortoni* in a layer, 1 foot above water level, and with light drab clay lenses in upper part	5
	Total	13

SECTIONS ALONG PAMUNKEY RIVER.

The Aquia formation occurs as a continuous bed for a distance of many miles along the Pamunkey River. It is, however, less fossiliferous here than along the Potomac River.

I. *Section right bank of Pamunkey River on farm at Reformatory, about one and one-half miles southeast of Hanover Courthouse.*

		Feet
Pleistocene	Coarse yellow sands, cross-bedded, with occasional gravel layers	12 to 15
Eocene. Aquia	Dark greenish-black micaceous sandy marl with many black grains of glauconite and a few shells	10
	Covered	6
	Total	31

II. *Section in small ravine about one-eighth mile southeast of Wickham.*

		Feet
Pleistocene	Concealed	3
	Coarse, yellowish-gray sand	6-8
Eocene. Aquia	Dark green to greenish-black marl, highly fossiliferous, the shells being much decomposed, among them being *Turritella mortoni, Crassatellites alaeformis,* and *Ostrea compressirostra*	5
	Coarse gravel bed with pebbles from ½ inch to 4 inches thick and with dark greensand lenses	2+
	Total	18

III. *Section along river road about three and one-half miles southeast of Hanover Courthouse.*

		Feet
Pleistocene	Yellowish sands with gravel	4-6
	Drab clay with yellow streaks	6-8
	Compact yellow sandy clay	1-
Eocene. Aquia	Weathered, incoherent, greensand, stained brown in places	3
	Total	18

IV. *Section along river road about four miles southeast of Hanover.*

			Feet
Pleistocene		Concealed	6
		Coarse yellow cross-bedded alternating sand and gravel layers with two layers of iron crusts at base between which is a very coarse gravel layer with large boulders of gneiss (1 to 2 feet in diameter). From this coarse gravel layer a stream issues	7
Eocene.	Aquia	Reddish-yellow weathered greensand marl with fossil impressions	1
		Dark green, glauconitic, micaceous, sandy clay with a few fossils, a small *Venericardia* being most abundant	15
		Total	29

V. *Section right bank Pamunkey River about seven miles southeast of Hanover Courthouse and two and one-half miles from Studley.*

			Feet
Pleistocene		Yellow sand and gravel	15
Eocene.	Aquia	Dark green glauconitic sand, coarse in lower portion and fine in upper, containing fossil impressions	4
		Layer of small dark-colored gravels, sharks teeth and bone fragments	2-3 in.
		Dark green glauconitic micaceous sandy marl with a few fossils	12
		Concealed	15
		Total	46 3 in.

A similar section is exposed on the right bank of the Pamunkey River about five miles northeast of Studley.

SECTIONS ALONG CHICKAHOMINY RIVER.

The Aquia formation has not thus far been observed along the Chickahominy River, but this is undoubtedly due to its being concealed from view by the recent swamp deposits that are so extensively developed in the river valley.

SECTIONS ALONG JAMES RIVER.

The Aquia formation is exposed at a number of localities in the James River valley from Richmond to City Point where it disappears beneath water level. It is by no means continuous between these points as most of the bluffs show Patuxent strata immediately overlain by Pleistocene sands and gravels. Also in one place the Piedmont crystalline rocks come to the

surface. The deposits consist almost entirely of glauconitic sand in which are occasional fossil casts although they are seldom abundant and in this respect form a striking contrast to the Aquia deposits exposed along the Potomac River.

In Richmond the Aquia is exposed in many places along Shockoe and Gillis creeks. A short distance south of the Locomotive Works a thickness of about 8 feet of Aquia is exposed and here it consists of a greenish-gray fine sand somewhat resembling in color a mixture of pepper and salt. It is overlain by impure diatomaceous earth belonging to the Calvert formation. The Aquia sand contains some glauconite though much less than occurs at most places. In the sand are numerous sharks teeth, fragments of bones, and a very few molluscan casts. Along Gillis Creek in the southeast portion of Richmond the Eocene is exposed in several places and the weathered greensand has been dug for use as moulding sand. It contains a few small pebbles and fossil casts.

I. *Section at Howlett House Bluff, right bank of James River, three and one-half miles east of Chester.*

			Feet
Pleistocene.	Sunderland	Yellow loam grading downward into mottled (red, drab, yellow) loam and then into coarse brown sand with few pebbles....	45
Miocene.	Calvert	Yellow sand, very fine, formerly shipped away in barges as a moulding sand. Upper part coarser than lower.................	35
		Compact clay, blue when fresh, pure white when dry	15
Eocene.	Aquia	Mottled light and dark grayish-green sand with considerable glauconite.............	15
Lower Cretaceous.	Patuxent	Conglomerate bed containing large and small cobbles, pebbles, etc., in matrix of coarse arkosic sand. Materials extremely variable. Lower part is in several places quite firmly indurated (exposed to water's edge)....	30
		Total..............................	140

II. *Section on James River, five miles above City Point.*

The Aquia formation outcrops above the water to a height of from 1 to 9 feet for a distance of about one-half to three-quarters of a mile above upper Shirley. It consists of dark, almost black, fine, argillaceous sand containing small pieces of mica and some casts of *Turritella mortoni* and pelecypods. The upper part where weathered is yellow.

SECTIONS ALONG NOTTOWAY RIVER.

The most southerly exposures of Eocene strata in Virginia occur near Bolling's Bridge on the Nottoway River where McGee[a] first reported the presence of three or four feet of dark-colored clay containing Eocene fossils. In the absence of any characteristic species this material is referred to the Aquia formation. It occurs in immediate contact with Potomac strata.

The Nanjemoy Formation.

Name and areal distribution.—This formation has been so named because of the excellent exposures of beds of this age along the Nanjemoy Creek, a stream flowing into the Potomac River from the Maryland side. The name was proposed by Clark and Martin in 1901.[b]

Stratigraphic relations.—The stratigraphic relations of the Nanjemoy formation are very simple. The formation rests conformably upon the Aquia, while it is covered by the deposits of the Calvert formation with which it is unconformable. The Calvert transgresses the Nanjemoy altogether in northeastern Maryland and probably also in southern Virginia, so that it comes to rest directly upon the Aquia, the Nanjemoy not appearing at the surface. It probably underlies the Calvert, however, throughout the entire eastern portion of the State. In certain places near the outcrop of the formation the Nanjemoy deposits are unconformably overlain by the unconsolidated materials of the Pleistocene.

Lithologic character.—The Nanjemoy formation is composed of greensand, often highly argillaceous and less frequently calcareous than the Aquia deposits, and with here and there layers containing abundant crystals and crystalline masses of gypsum. The base of the Nanjemoy is usually marked by a bed of compact white and pink clay resting directly upon the greensand of the Aquia. This clay bed forms a very persistent layer which has received the name of Marlboro clay from Marlboro, Maryland, where it is well exposed.

Strike, dip, and thickness.—The strike of the Nanjemoy is almost due north and south, while the beds dip to the east at the rate of from 12 to 15 feet to the mile. In the deep wells in the vicinity of Norfolk the Nanjemoy is reached at the depth of about 600 feet. The thickness where all the beds are developed is about 125 feet. It generally thins somewhat to the westward, as in the case of most of the Coastal Plain formations.

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[a]Amer. Jour. Sci., vol. xxxv, 1888, p. 126.

[b]Eocene, Maryland Geological Survey, p. 64.

Division.—The Nanjemoy formation has been divided into two members known as the *Potopaco* clay member and *Woodstock* greensand marl member, the former having a thickness of from 60 to 65 feet and the latter from 50 to 60 feet. The Potopaco member is composed of greensand, often very argillaceous and at times gypseous. The clayey character of this member especially in its lower portions is in marked contrast to the more highly glauconitic beds of the Aquia formation below. The Woodstock member is characterized by fine homogeneous greensands and greensand marls that are much less argillaceous than the underlying Potopaco beds. The Potopaco member in the Potomac region is subdivided into six zones and the Woodstock member into two zones. The two members show paleontological differences to which reference will be made again later.

Paleontologic character.—The fossils of the Nanjemoy are not quite so plentiful as in the Aquia formation yet locally they are very abundant. All of the chief groups of the invertebrates are represented, as well as fishes, and a few plant remains. The latter consist of some small lignitized nuts found along the Potomac River near Popes Creek, Maryland. In 1850 a fossil nut the size of a large hickory nut was described by Ruffin, from the Eocene of the Pamunkey, probably from the Nanjemoy. As in the case of the Aquia, the molluscs predominate. The most widely distributed and abundant form is *Venericardia potapacoensis,* it being found in almost every exposure of Nanjemoy greensand.

Among the forms which are limited to the Nanjemoy formation but found in both members are:

Meretrix ovata var. *ovata* (Rogers)
Lucina dartoni Clark
Lucina whitei Clark
Venericardia potapocoensis Clark & Martin
Ostrea sellaeformis Conrad
Leda improcera (Conrad)
Leda potomacensis Clark & Martin
Leda tysoni Clark & Martin
Nucula potomacensis Clark & Martin

The following species have been found only in the Potopaco member:

Cypraea smithi Aldrich
Solen lisbonensis Aldrich
(?) *Lucina astartiformis* Aldrich
Periploma sp.
Ceriopora micropora Goldfuss

The following species among others are found only in the Woodstock member:

Galeocerdo latidens Agassiz
Levifusus trabeatus (?) Conrad
Pyrula penita Conrad var.
Turritella potomacensis Clark & Martin
Dentalium minutistriatum Gabb
Meretrix lenis (Conrad)
Venericardia marylandica Clark & Martin
Modiolus marylandicus Clark & Martin
Leda parva (Rogers)
Carpolithus marylandicus Hollick

Areal distribution.—The Nanjemoy formation outcrops along a narrow belt to the east of the Aquia formation. It is well exposed where the Aquia disappears beneath tide. The Nanjemoy is also exposed in the lower courses of most of the tributary streams flowing into the Potomac and Rappahannock rivers in the eastern part of King George and Caroline counties, along the Pamunkey River between King William and Hanover counties, and along the James River in the vicinity of City Point. The upper surface of the Nanjemoy disappears below tide just below Mathias Point on the Potomac, a short distance below Port Royal on the Rappahannock, and at the mouth of Powells Creek, about seven miles below City Point on the James River. The Nanjemoy has not been recognized on the Nottoway River.

DETAILED SECTIONS.

SECTIONS ALONG POTOMAC RIVER.

The sections of the Nanjemoy formation exposed along the Potomac River and its tributaries are among the best to be found in the State. They occur in King George County where the current of the river is deflected against the Virginia shore on account of the river turning sharply to the left at this point. Prominent bluffs result from the erosive action of the water and in these bluffs are many good exposures of Nanjemoy strata. At Mathias Point the river turns somewhat less abruptly to the right and high bluffs have been formed on the Maryland shore near Pope's Creek. A few sections from near that place are included to show the characteristics of the entire formation along the valley of the Potomac River.

I. *Section on the south side of Potomac Creek, about one and one-half miles east of the railroad.*

				Feet
Eocene.	Nanjemoy	Potapaco	Gray sand with some glauconite, and a few casts	12
			Very compact white clay blotched with limonite stains	7
			Compact pink clay, no fossils	17
	Aquia	Paspotansa	Glauconitic sand with occasional layers of fossil casts	30
			Total	66

II. *Section right bank of Potomac River three miles below Potomac Creek.*

		Feet
Pleistocene	Sand and gravel	2
Eocene. Nanjemoy Potapaco	Greenish-gray argillaceous sand (Zone 15)	4
	Greenish-gray argillaceous sand with gypsum crystals (Zone 14)	5
	Light gray greensand with band containing *Venericardia potapacoensis* (Zone 13)	4
	Greenish-gray argillaceous sand (Zone 12)	10
	Indurated greensand with *Venericardia potapacoensis* (Zone 11)	1
	Total	26

III. *Section right bank of Potomac River, center of bluff at Woodstock.*

		Feet
Pleistocene	Yellow and orange-colored sands and gravel	25
Miocene. Calvert	Diatomaceous earth with Miocene fossils	5
Eocene. Nanjemoy Woodstock	Argillaceous greensand (Zone 17	6
	Dark greensand more or less argillaceous with *Mitra potomacensis, Mesalia obruta, Strepsidura subscalarina, Turritella potomacensis, Corbula oniscus, Meretrix subimpressa, Protocardia lenis, Pecten dalli, Ostrea sellaeformis, Glycymeris idoneus* and *Leda cultelliformis* (Zone 16)	20
Potapaco	Greensand with *Tornatellaea bella, Cylichna venusta, Ringicula dalli, Venericardia potapacoensis* and other forms (Zone 15)	6
	Total	62

IV. *Section two miles west of Passapatanzy, along hillside.*

		Feet
Pleistocene	Gravel and loam	10
Miocene. Calvert	Diatomaceous earth	25
	Blue and drab clay with a few fossil impressions	6
Eocene. Nanjemoy	Greensand, exposed	3
	Total	44

V. *Section left bank of Potomac River, three miles above Pope's Creek.*

		Feet
Pleistocene	Gravel and sand	3
Eocene. Nanjemoy Potapaco	Argillaceous greensand (Zone 15)	6
	Greensand with gypsum crystals (Zone 14)	5
	Total	14

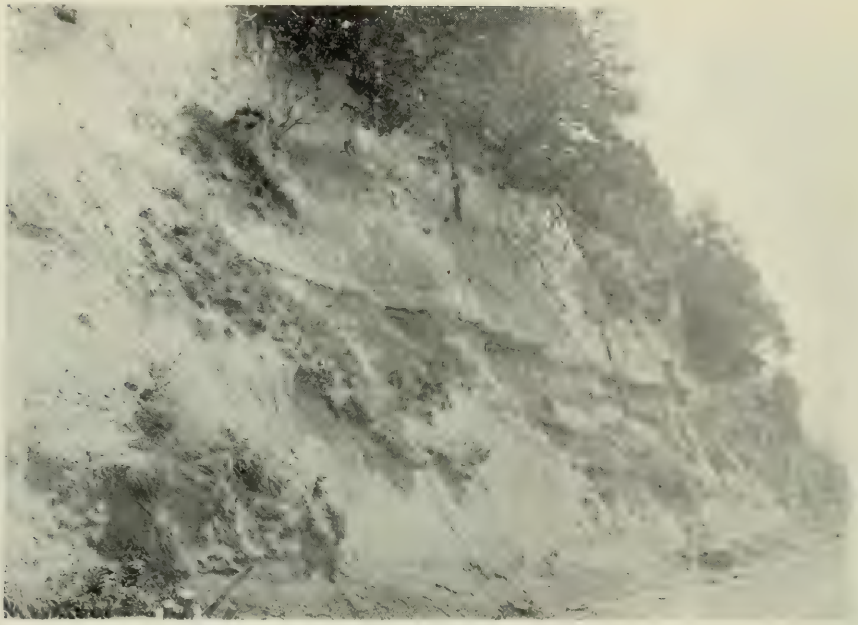

Fig. 1.—Bluff at Popes Creek, Potomac River, Maryland, showing zone 17 of Nanjemoy formation overlain by diatomaceous earth beds of Calvert formation.

Fig. 2.—Bluff at Hopyard, Rappahannock River. Showing calcareous concretions of Aquia formation.

NANJEMOY AND AQUIA FORMATIONS.

VI. *Section left bank of Potomac River two and one-quarter miles above Pope's Creek, Md.*

			Feet
Miocene.	Calvert	Diatomaceous earth	10
Eocene.	Nanjemoy Woodstock	Greensand with fossil casts (Zone 17)	10
		Greensand, somewhat argillaceous (Zone 10)	30
	Potapaco	Grayish black argillaceous greensand (Zone 15) with numerous bands of *Venericardia potapacoensis* and other fossils, overlain by a band of concretions	5
		Total	55

VII. *Section of bluff left bank of Potomac River, one mile below Pope's Creek, Md.*

			Feet	Inches
Miocene.	Calvert	Diatomaceous earth	40	
Eocene.	Nanjemoy Woodstock	Brown glauconitic clay much oxidized in places	2	
		Band of pinkish-brown clay nodules in glauconitic clay	0	6
		Dark glauconitic clay with many fossil casts	4	
		Concretions with occasional fossils	0	6
		Argillaceous greensand with many casts and occasional shells	3	
		Concretions with many large specimens of *Hercoglossa tuomeyi*	0	6
		Argillaceous greensand with abundant fossils including *Meretrix subimpressa, Venericardia potapacoensis, Hercoglossa tuomeyi, Turritella potomacensis, Mesalia obruta, Protocardia lenis, Modiolus alabamensis, Corbula subengonata, Mitra potomacensis*, and many other forms (Zone 17)	6	
		Total	56	6

SECTIONS IN THE RAPPAHANNOCK RIVER VALLEY.

The Nanjemoy formation is exposed in many places along the Rappahannock River. The finest exposures are in those places where the river in its meanders cuts into the valley bluffs. In such places the bluffs are high and the Nanjemoy strata well exposed in a few places, although the covering of vegetation and the landslides occasionally conceal the undisturbed strata.

In a cut on the R. F. & P. R. R. between Potomac Creek and Rappahannock River about 3½ miles north of Fredericksburg, there is an exposure of Nanjemoy and Aquia strata. At the south end of

the cut a few feet of Potomac arkosic sand appears overlain by Eocene greensand. In the centre of the cut the Nanjemoy clay is exposed. At a few places along the base the Eocene is dark green and unweathered but for the most part it is weathered to lighter shades, and more or less mottled with buff. The cut is about 35 feet deep.

I. *Section left bank of Rappahannock River at Hopyard.*

			Feet
Pleistocene		Yellow sand and gravel....................	12
Eocene.	Nanjemoy and Aquia	Argillaceous greensand......................	35-40
		Total..............................	52
		Above the wharf the upper part of the bluff is not well exposed. Near the base the following Aquia fossils were obtained: *Turritella mortoni, Arca* (?), *Crassatellites, Meretrix, Ostrea compressirostra, Corbula.* Below the wharf a few hundred yards and near the top of the Eocene several thin layers of Nanjemoy fossils occur. The principal form is *Venericardia potapacoensis.* This is the first appearance of the Nanjemoy formation on the Rappahannock River. The fossiliferous material is a clay rather than a sand although it is somewhat arenaceous. Many of the shells in this place are waterworn.	

II. *Section right bank of Rappahannock River, two and one-half miles below Hopyard.*

Eocene.	Nanjemoy and Aquia	The bluff is about 40 to 50 feet high. Not well exposed except near base where about 10 feet of fossiliferous Eocene greensand outcrops in which are *Turritella mortoni, Meretrix subimpressa, Crassatellites alaeformis* and *Lunatia marylandica.* The Nanjemoy is undoubtedly present in the concealed portion of the bluff.

III. *Section right bank of Rappahannock River one and one-half miles below the mouth of Mount Creek.*

			Feet
Pleistocene		Coarse yellow sand and gravel..............	30
Eocene.	Nanjemoy	Dark green finely arenaceous and micaceous clay. Fossils occur in the lower 6 feet. *Venericardia potapacoensis, Meretrix subimpressa, Corbula oniscus* are abundant. The fossils are broken and water-worn and in this respect resemble the layer at Hopyard containing *Venericardia potapacoensis.* It is probably the same horizon....	18
		Total..............................	48

On the left bank of the Rappahannock River two and one-half miles above Port Conway, in a bluff 25 to 30 feet in height, some weathered greensand is exposed near the base. The greater portion of the bluff consists of Pleistocene materials.

IV. *Section left bank of Rappahannock River, about three-quarters of a mile above Port Conway.*

			Feet
Pleistocene		Sand, gravel, etc., not well exposed, about..	15
Eocene.	Nanjemoy	Dark green arenaceous glauconitic clay. Fossils especially in bed 4 feet thick at base of cliff and in a band 12 to 16 feet above base. The fossils in the lower stratum are as follows: *Venericardia potapacoensis, Corbula oniscus, Meretrix lenis? Ostrea Venercardia, sp., Meretrix ovata, Turbonilla potomacensis*, etc. The fossils from the upper zone are *Venericardia potapacoensis, Meretrix, Turritella*, etc.	25
		Total...............................	40

The Nanjemoy formation outcrops just above Port Conway for a distance of about three-quarters of a mile. In some places it extends to a height of 18 feet above the water. It consists of a compact argillaceous greensand with a few layers of fragile shells principally *Venericardia potapacoensis*. On the Port Royal side the Nanjemoy also outcrops in the river bluff but the exposed thickness is not more than 10 or 12 feet. Shell layers here consist mainly of *Venericardia potapacoensis* and *Turritella* sp. Pleistocene materials overlie the Nanjemoy strata on both sides of the river.

On the south bank of the Rappahannock River between Port Royal and the mouth of Mill Creek, Nanjemoy greensand is poorly exposed in several places.

V. *Section left bank of Rappahannock River two miles below Port Conway.*

			Feet
Pleistocene		Sand and gravel............................	12
Eocene.	Nanjemoy	Dark argillaceous greensand containing fossils at base..................................	10
		Total...............................	22

VI. *Section left bank of Rappahannock River three-quarters of a mile east of the mouth of Jetts Creek.*

			Feet
Pleistocene		Sand and gravel	10
Eocene.	Nanjemoy	Argillaceous greensand more or less weathered. Contains a few casts, among which are specimens of *Corbula aldrichi*	20
		Total	30

SECTIONS IN THE MATTAPONI RIVER VALLEY.

Along the Mattaponi River the Nanjemoy is exposed at the base of the bluffs for a considerable distance with the upper portion of the bluffs composed of diatomaceous earth or blue argillaceous sand belonging to the Calvert formation. This line of contact, although undulating, is far more regular than one would expect to find, for an extensive erosion interval separates the two formations. The contact is usually about 15 to 20 feet above the level of the water in the river.

I. *Section left bank of Mattaponi River about one-half mile below crossing of the County road leading from Penola to Shumansville.*

			Feet
Pleistocene		Sand and gravel, not well exposed	8-10
Eocene.	Nanjemoy	Dark, compact greensand containing casts of *Venericardia potapocoensis*	1½
	Aquia	Glauconitic sand separated from the overlying bed by a ferruginous sand layer	6½
		Total	18

II. *Section left bank of Mattaponi River three or four miles below the preceding locality.*

A terrace, about 45 feet above the river level comes close to the river at this point. There is no good section in the river bluff but by following a short distance up a ravine the following imperfect section was observed.

			Feet
Pleistocene (?)		Concealed about	20
Miocene.	Calvert	Olive green or greenish-gray sandy clay about	18
Eocene.	Nanjemoy	Compact greensand about	7
		Total	45

A fairly good exposure of the Calvert-Nanjemoy contact was seen at one place, where it was sharp and decidedly undulating.

About 1½ miles below the preceding, the greensand appears at the base of a 15-foot terrace. The exposure is a few rods back from the river bank. This locality is about one-half mile below the mouth of Pole Cat Creek.

III. *Section left bank of Mattaponi River about one-half mile below the preceding, one-half mile above Burke's Bridge.*

			Feet
Pleistocene (?)		Concealed	14
Eocene.	Nanjemoy	Compact greensand with impressions of *Venericardia potapacoensis*	12
		Total	26

At Burke's Bridge and for several miles below, Eocene greensand is occasionally seen at the base of a 15 or 20-foot terrace.

IV. *Section left bank of Mattaponi River three or four miles below Burke's Bridge.*

			Feet
Pleistocene		Concealed	8 or 10
Eocene.	Nanjemoy	Compact greensand containing fossils in lower 2 feet. Principal fossil is *Venericardia potapacoensis*. A few other small pelecypods are present	8
		Total	18

For several miles below the preceding locality Eocene greensand appears at the base of low sections rising in places to about 10 feet above the water. At a point between 6 and 8 miles below Burke's Bridge the river strikes a high upland. When it first touches it the slope is concealed by vegetation but about one-quarter mile below this point the following section could be made out, although the exposure is very poor.

V. *Section Mattaponi River eight miles below Burke's Bridge and one and one-half miles above Reedy's Mill Bridge.*

			Feet
Pleistocene (?)		Concealed ....about	22
Miocene.	Calvert	In the upper part 10 or 15 feet of greenish clay with casts of *Turritella plebeia* and in the lower part 6 or 8 feet of grayish argillaceous sand with a 1-foot gravel band along base containing quartz and phosphate pebbles and sharks teeth. The pebbles are all small............................	30
Eocene.	Nanjemoy	Grayish glauconitic sand	5
		Concealed	23
		Total..............................	80

Eocene greensand appears at the base of low sections for the first 1½ miles below Reedy's Mill Bridge. The river then impinges on the upland on the left and the following section is exposed.

VI. *Section left bank of Mattaponi River, one and one-half miles below Reedy's Mill Bridge.*

			Feet
Pleistocene (?)		Concealed	20
Miocene.	Calvert	Greenish clay with casts of *Turritella;* impure diatomaceous earth in lower part	24
		Greenish argillaceous sand consisting principally of reworked Eocene greensand with a thin band of quartz pebbles, phosphate pebbles, sharks teeth, and pieces of bones more or less water-worn at base..........	10
Eocene.	Nanjemoy	Greensand with some pelecypod casts	26
		Total..............................	80

VII. *Section left bank of Mattaponi River two and one-half or three miles below Reedy's Mill Bridge.*

			Feet
Pleistocene		Concealed except gravel band at base.........	11
Eocene.	Nanjemoy	Dark green arenaceous glauconitic clay with a band of water-worn fossils near the base; *Venericardia potapacoensis* abundant; also *Pecten, Ostrea, Meretrix,* etc..................	10
		Total..............................	21

About 4½ or 5 miles below Reedy's Mill Bridge a few Nanjemoy fossils, principally *Venericardia potapacoensis,* were collected in a section similar to the preceding. From the preceding locality to the mouth of Marricossick Creek, a distance of about 5 miles, Nanjemoy greensand and dark green clay continue to form the base of low sections. At one point a few miles above the mouth of the creek on the right the upland is washed by the river. The high river bluff resulting is not well exposed but 30 or 40 feet above the base greenish Miocene clays were observed, containing casts of *Turritella plebeia.*

VIII. *Section on Mattaponi River at the mouth of Marricossick Creek.*

			Feet
Pleistocene		Sand and gravel	4
Eocene.	Nanjemoy	Dark green argillaceous greensand	12
		Total	16

About two miles below the mouth of Marricossick Creek the river touches the base of a high upland rising 100 feet or more above the water level. The bluff is overgrown with vegetation to such an extent that only about 8 feet of Eocene greensand is exposed at the base. A number of fossils are present in this basal bed, among them being *Venericardia potapacoensis,* a number of small pelecypods, and some gastropods.

From the mouth of Marricossick Creek to the first county bridge below, a distance of about 5 miles, the Eocene greensand continues to appear at the base of a Pleistocene terrace. Not far above the bridge the Nanjemoy strata rise as much as 15 feet above the level of the water. On the left near the end of the bridge the road ascends a scarp some 25 or 30 feet above the river level. Toward the top light-colored clays of the Calvert formation are poorly exposed in the road.

IX. *Section right bank of Mattaponi River, eleven miles below mouth of Marricossick Creek.*

			Feet
Pleistocene		Sand and gravel	8
Miocene.	Calvert	Dark greenish clay at top grading downward into greenish argillaceous sand which has been derived from the Eocene and reworked. Along the base a thin band of gravel consisting of quartz and phosphate pebbles, etc., occurs	23
Eocene.	Nanjemoy	Greensand	4
		Total	35

About three miles below the preceding locality, a very similar section occurs on the left bank of the river, the chief difference being that only one foot of Nanjemoy materials appears at the base.

X. *Section Mattaponi River, about fifteen and one-half miles below the mouth of Marricossick Creek.*

			Feet
Pleistocene		Sand and gravel	5
Miocene.	Calvert	Greenish sandy clay	8½
Eocene.	Nanjemoy	Greenish arenaceous clay	1½
		Total	15

SECTIONS IN THE PAMUNKEY RIVER VALLEY.

The Nanjemoy formation outcrops along the Pamunkey River in many places although good exposures of the strata are few in number.

I. *Section right bank of Pamunkey River at Newcastle about one mile by road above Newcastle Bridge.*

			Feet
Pleistocene		Coarse yellow sand with small gravel	5
Eocene.	Nanjemoy	Coarse gray calcareous sandy marl containing small pebbles, glauconitic sand grains, and occasional fossiliferous layers. Among the fossil forms observed were *Venericardia* and *Ostrea sellaeformis*	7
		Concealed	12
		Total	24

At a spring just west of Newcastle Bridge on Pamunkey River at bend in the river the gray calcareous Nanjemoy marl similar to that at Newcastle outcrops. Above it is a heavy bed of reddish-yellow sand 12 to 15 feet thick.

About a mile east of Newcastle Bridge on the River Road, the Nanjemoy outcrops in the road. It is similar to that at Newcastle and contains similar fossils. Above it, there was found a coarse greensand layer with sharks teeth, bones and gravel at its base. This seems to belong to the Calvert formation and represents material derived from the Nanjemoy and reworked by the ocean waves during Miocene time.

On the right bank of the Pamunkey River at "Farmington," about one mile from Apperson's store and about three-quarters of a mile east of Newcastle Bridge, 6 feet of gray calcareous sandy marl containing glauconite similar to that at Newcastle is exposed at the base of a high bluff.

II. *Section right bank of Pamunkey River at mouth of Matadequin Creek.*

At this point marl works were established some years ago and the greensand marl dug, sifted, and sold as a fertilizer. The section is as follows:

			Feet
Pleistocene		Light colored yellow sand....................	4
Miocene.	Calvert	White friable sandy clay with fine gravel, fossil casts, and sharks teeth..................	6
		Olive green compact sandy clay stained brown in places..............................	4-6
		Layer of small gravel containing bones and sharks teeth...........................	2 in.
Eocene.	Nanjemoy	Dark green, glauconitic, sandy marl (exposed)	2-3
		Total...............................	19+

SECTIONS IN THE JAMES RIVER VALLEY.

The Nanjemoy formation has a very limited distribution along the James River and there are few good exposures. The formation has not been recognized south of the James and probably does not extend much farther south. It is not exposed along the Nottoway or Meherrin rivers and is positively known to be absent in the Roanoke River valley. The formation in its most southerly exposures has not lost its typical characteristics as the following sections will show, but instead resembles the Nanjemoy strata of Maryland even more than those of the Pamunkey River valley.

I. *Section right bank of James River, two miles below City Point.*

			Feet
Pleistocene		Loam with gravels at base..................	8
Miocene.	Calvert	Shell marl, shells in buff to gray sand: common species are *Chama*, *Ecphora*, *Venus*, *Pecten*, *Perna*, *Crucibulum* *Crepidula*, *Oliva*, *Discinisca*, *Ostrea*, etc.	5
		Poor exposure, seems to be sand without fossils	7
		Shell bed, similar to above except without *Ecphora*, *Discinisca*, *Oliva* and *Perna*......	4
Eocene.	Nanjemoy	Marlboro pink to white to drab clay, very compact	3-5
	Aquia (?)	Glauconitic sand containing much gypsum, in places exposed to water................	15
		Total...............................	44

On the right bank of the James River, two and three-quarters miles below City Point greensand marl was formerly dug, dried and shipped to fertilizer factories. The section is about the same as that at the preceding locality. The Eocene greensand is directly overlain by Miocene shell marl and no diatomaceous earth appears. The Pleistocene is thicker, however, and the bluff higher than in the section given above. The marl was dug at this place for about twelve years, but in 1906 a great piece of the bank slid down and crushed the mill and covered up the pits, since which time the plant has been abandoned.

II. *Section right bank of James River, just below Indian Field Point, six miles below City Point.*

			Feet
Pleistocene		Buff to brown loose sand with a thick bed of pebbles near base not well exposed........	25
		Bluff concealed by vegetation and by landslides	15
Miocene.	Calvert	Thin band of Miocene shell marl in buff sand matrix, whole layer somewhat disturbed as the result of landslides. *Arca centenaria* was the only perfect fossil observed........	3
Eocene.	Nanjemoy	Shell layer, many rotten shells and great numbers of *Ostrea sellaeformis*.................	2
		Glauconitic sand, decidedly argillaceous, mainly concealed by vegatation to water's edge, formerly dug for fertilizing material........	30
		Total...............................	75

All along the river in this section there have been great landslides that have formed a distinct terrace which is now cultivated. The terrace is from 25 to 75 yards wide.

III. *Section right bank of James River at Coggins Point, nine miles below City Point.*

			Feet
Pleistocene		Coarse sand containing many pebble lenses....	20
		Pebble and cobble band......................	10-15
Eocene.	Nanjemoy	Clay mottled, exposed..........	4
		Concealed by vegetation to water............	18-20
		Total...............................	59

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	Fort Washington.	Tinkers Creek, near Piscataway.	1 mile N. E. of Piscataway.	Piscataway Creek.	Swan Creek, near Piscataway.	Pomonkey Neck.	Glymont.	1 mile S. E. of Mason Springs.	Mattawoman Creek.	Reedy Run.	Liverpool Point.	Wades Bay.	Clifton Beach.	Aquia Creek.	Potomac Creek.	Paspotansa Creek.	2 miles below Potomac Creek.	1 mile below Massaponax Creek.	3 miles below Massaponax Creek.	1¼ mile above Ware Creek.	Radcliffe's Wharf.	Above Hopyard Wharf.	2½ miles below Hopyard Wharf.	Near Brooke.	Mattaponi River, R. F. and P. R. R. Bridge.	Mattaponi River, first county bridge below R. R.	Pamunkey River, ⅛ mile S. E. of Wickham.	James River, Richmond.	James River, Deep Bottom.	James River, City Point.
	AQUIA FORMATION.																													
	POTOMAC RIVER.																	RAPPAHANNOCK RIVER.							MATTAPONI RIVER.		PAMUNKEY RIVER.	JAMES RIVER.		
REPTILIA.																														
Thecachampsa sp.											*		*																	
Thecachampsa contusor Cope														*																
Thecachampsa marylandica Clark													*																	
Euclastes ? sp.													*																	
Trionyx virginiana Clark														*																
PISCES.																														
Myliobatis copeanus Clark							*				*		*	*	*															
Aetobatis arcuatus Agassiz							*							*																
Synechodus clarkii Eastman								*			*																			
Odontaspis elegans (Agassiz)	*										*			*																
Odontaspis macrota (Agassiz)	*									*				*																
Odontaspis cuspidata (Agassiz)	*								*		*																			
Otodus obliquus Agassiz							*				*			*																
Carcharodon auriculatus (Bln.)																														
Galeocerdo latidens Agassiz																														
Sphyrna prisca Agassiz											*																			
Xiphias ? radiata (Clark)													*																	
ARTHROPODA. Ostracoda.																														
Cytheridea perarcuata Ulrich															*															
MOLLUSCA. Cephalopoda.																														
Hercoglossa tuomeyi C. & M.													*																	
MOLLUSCA. Gastropoda.																														
Tornatellaea bella Conrad			*											*	*															
Ringicula dalli Clark																														
Cylichna venusta Clark			*					*					*		*		*													
Pleurotoma harrisi Clark								*							*		*													
Pleurotoma potomacensis C. & M.			*														*													
Pleurotoma ducateli C. & M.								*																						
Pleurotoma childreni Lea								*									*													
Pleurotoma piscatavensis C. & M.			*																											
Pleurotoma tysoni C. & M.								*																						
Mangilia bellistriata Clark															*															
Cancellaria sp.															*		*													
Cancellaria graciloides Ald. *var.*								*																						
Cancellaria potomacensis C. & M.								*																						
Olivula sp.																														
Volutilithes sp.														*	*															
Caricella pyruloides ? (Conrad)											*			*	*															
Mitra marylandica ? Clark						*																								
Mitra pomonkensis C. & M.			*			*									*		*													

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	NANJEMOY FORMATION.																								
	POTOMAC RIVER.									RAPPAHANNOCK RIVER.			MATTAPONI RIVER.								PAMUNKEY RIVER.		JAMES RIVER.		
	Potomac Creek.	Nanjemoy Creek.	½ mile below Chapel Point.	2½ miles above Popes Creek.	Woodstock. Zone 15.	2 miles above Popes Creek.	1½ mile above Popes Creek.	Popes Creek.	Woodstock. Zones 16 and 17.	Rappahannock River, Hopyard.	1½ mile below Mount Creek.	¾ mile above Port Conway.	2 miles below Port Conway.	Mattaponi River, ½ mile below county bridge to Penola.	½ mile above Burke's Bridge.	3 to 4 miles below Burke's Bridge.	2½ miles below Reedy's Mill Bridge.	4¾ miles below Reedy's Mill Bridge.	2 miles below Marriccossick Creek.	3 miles below Marriccossick Creek.	Pamunkey River, Newcastle.	Pamunkey River, 1 mile east of Newcastle.	James River, Tar Bay.	James River, Evergreen.	James River, Indian Field Point.
REPTILIA.																									
Thecachampsa sp.																									
Thecachampsa contusor Cope																									
Thecachampsa marylandica Clark																									
Euclastes ? sp.																									
Trionyx virginiana Clark																									
PISCES.																									
Myliobatis copeanus Clark									*																
Aetobatis arcuatus Agassiz								*																	
Synechodus clarkii Eastman																									
Odontaspis elegans (Agassiz)																									
Odontaspis macrota (Agassiz)									*																
Odontaspis cuspidata (Agassiz)								*	*																
Otodus obliquus Agassiz																									
Carcharodon auriculatus (Bln.)								*																	
Galeocerdo latidens Agassiz									*																
Sphyrna prisca Agassiz																									
Xiphias ? radiata (Clark)																									
ARTHROPODA. Ostracoda.																									
Cytheridea perarcuata Ulrich									*																
MOLLUSCA. Cephalopoda.																									
Hercoglossa tuomeyi C. & M.								*																	
MOLLUSCA. Gastropoda.																									
Tornatellaea bella Conrad					*				?																
Ringicula dalli Clark									*																
Cylichna venusta Clark		*			*				?																
Pleurotoma harrisi Clark																									
Pleurotoma potomacensis C. & M.																									
Pleurotoma ducateli C. & M.																									
Pleurotoma childreni Lea.																									
Pleurotoma piscatavensis C. & M.																									
Pleurotoma tysoni C. & M.																									
Mangilia bellistriata Clark								*																	
Cancellaria sp.																									
Cancellaria graciloides Ald. *var.*																									
Cancellaria potomacensis C. & M.																									
Olivula sp.								*																	
Volutilithes sp.																									
Caricella pyruloides ? (Conrad)																									
Mitra marylandica ? Clark																									
Mitra pomonkensis C. & M.																									

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	AQUIA FORMATION.																													
	POTOMAC RIVER.																RAPPAHANNOCK RIVER.							MATTAPONI RIVER.		PAMUNKEY RIVER.	JAMES RIVER.		
	Fort Washington.	Tinkers Creek, near Piscataway.	1 mile N. E. of Piscataway.	Piscataway Creek.	Swan Creek, near Piscataway.	Pomonkey Neck.	Glymont.	1 mile S. E. of Mason Springs.	Mattawoman Creek.	Reedy Run.	Liverpool Point.	Wades Bay.	Clifton Beach.	Aquia Creek.	Potomac Creek.	Paspotansa Creek.	2 miles below Potomac Creek.	1 mile below Massaponax Creek.	3 miles below Massaponax Creek.	1¼ mile above Ware Creek.	Radcliffe's Wharf.	Above Hopyard Wharf.	2½ miles below Hopyard Wharf.	Near Brooke.	Mattaponi River, R. F. and P. R. R. Bridge.	Mattaponi River, first county bridge below R. R.	Pamunkey River, ⅛ mile S. E. of Wickham.	James River, Richmond.	James River, Deep Bottom.	James River, City Point.
Mitra potomacensis C. & M.			*											*																
Latirus marylandicus C. & M.														*			*													
Fusus ? subtenuis Heilprin																	*													
Fusus ? interstriatus Heilprin			*											*																
Trophon sublevis Harris			*																											
Strepsidura subscalarina Heilprin											*				*		*													
Melongena ? potomacensis C. & M.															*															
Tudicla marylandica C. & M.	*																*													
Tudicla sp.	*						*						*	*																
Tudicla ? sp.													*	*																
Levifusus trabeatus ? Conrad																														
Metula marylandica C. & M.								*							*		*													
Chrysodomus engonatus (Heilprin)															*		*													
Tritonium showalteri (Conrad)																*	*													
Pyrula penita var. Conrad																														
Pyrula ? sp.																														
Fulguroficus argutus Clark						*									*		*													
Fusoficula juvenis (Whitfield)																	*													
Morio brevidentata (Aldrich)								*									*													
Cypraea smithi Aldrich																														
Calyptraphorus trinodiferus Conrad															*		*													
Calyptraphorus trinodiferus ? var.								*																						
Aporrhais potomacensis C. & M.			*												*	*	*													
Turritella humerosa Conrad	*	*	*				*	*			*		*	*		*														
Turritella mortoni Conrad	*	*	*				*	*			*		*	*		*		*	*	*	*	*	*		*				*	*
Turritella potomacensis C. & M.																														
Mesalia obruta (Conrad)																														
Natica cliftonensis Clark													*																	
Vermetus sp.				*											*															
Lunatia marylandica Conrad	*		*				*	*			*			*	*	*	*			*	*		*							
Calyptraea aperta (Solander)	*						*	*			*		*	*	*		*													
Litiopa marylandica C. & M.																	*													
Solarium sp.								*						*																
Scala virginiana Clark														*	*															
Scala potomacensis C. & M.																	*													
Scala sessilis Conrad																	*													
Scala carinata Lea																	*													
Turbonilla potomacensis C. & M.															*		*													
Tuba marylandica C. & M.								*								*														
Odostomia trapaquara (Harris)															*		*													
Niso umbilicata (Lea)															*															
Gibbula glandula (Conrad)				*											*															
Calliostoma sp.																	*		*											
MOLLUSCA. Scaphopoda.																														
Dentalium minutistriatum Gabb																														
Cadulus abruptus Meyer & Aldich			*								*		*	*																
MOLLUSCA. Pelecypoda.																														
Teredo virginiana Clark			*					*					*				*													
Gastrochaena sp.														*																
Phenacomya petrosa (Conrad)	*			*									*	*																

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	Nanjemoy Formation.																								
	Potomac River.									Rappahannock River.			Mattaponi River.								Pamunkey River.		James River.		
	Potomac Creek.	Nanjemoy Creek.	½ mile below Chapel Point.	2½ miles above Popes Creek.	Woodstock. Zone 15.	2 miles above Popes Creek.	1½ mile above Popes Creek.	Popes Creek.	Woodstock. Zones 16 and 17.	Rappahannock River, Hopyard.	1½ mile below Mount Creek.	¾ mile above Port Conway.	2 miles below Port Conway.	Mattaponi River, ½ mile below county bridge to Penola.	½ mile above Burke's Bridge.	3 to 4 miles below Burke's Bridge.	2½ miles below Reedy's Mill Bridge.	4¾ miles below Reedy's Mill Bridge.	2 miles below Marriccossick Creek.	3 miles below Marriccossick Creek.	Pamunkey River, Newcastle.	Pamunkey River, 1 mile east of Newcastle.	James River, Tar Bay.	James River, Evergreen.	James River, Indian Field Point.
Mitra potomacensis C. & M.								*	*																
Latirus marylandicus C. & M.																									
Fusus ? subtenuis Heilprin																									
Fusus ? interstriatus Heilprin									*																
Trophon sublevis Harris																									
Strepsidura subscalarina Heilprin								*	*																
Melongena ? potomacensis C. & M.																									
Tudicla marylandica C. & M.																									
Tudicla sp.																									
Tudicla ? sp.								*																	
Levifusus trabeatus ? Conrad								*	*																
Metula marylandica C. & M.																									
Chrysodomus engonatus (Heilprin)																									
Tritonium showalteri (Conrad)																									
Pyrula penita var. Conrad								*																	
Pyrula ? sp.								*																	
Fulguroficus argutus Clark																									
Fusoficula juvenis (Whitfield)																									
Morio brevidentata (Aldrich)																									
Cypraea smithi Aldrich		*	*																						
Calyptraphorus trinodiferus Conrad	*																							*	
Calyptraphorus trinodiferus ? var.								*																	
Aporrhais potomacensis C. & M.																									
Turritella humerosa Conrad																									
Turritella mortoni Conrad																									
Turritella potomacensis C. & M.								*	*																
Mesalia obruta (Conrad)								*	*			*													
Natica cliftonensis Clark									?																
Vermetus sp.																									
Lunatia marylandica Conrad					*				?																
Calyptraea aperta (Solander)			*					*	*																
Litiopa marylandica C. & M.																									
Solarium sp.																									
Scala virginiana Clark																									
Scala potomacensis C. & M.																									
Scala sessilis Conrad																									
Scala carinata Lea.																									
Turbonilla pottomacensis C. & M.																									
Tuba marylandica C. & M.								*																	
Odostomia trapaquara (Harris)																									
Niso umbilicata (Lea)																									
Gibbula glandula (Conrad)																									
Calliostoma sp.																									
MOLLUSCA. Scaphopoda.																									
Dentalium minutistriatum Gabb								*																	
Cadulus abruptus Meyer & Aldrich		*		*			*		*			*													
MOLLUSCA. Pelecypoda.																									
Teredo virginiana Clark			*	*				*																	
Gastrochaena sp.																									
Phenacomya petrosa (Conrad)																									

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	AQUIA FORMATION.																													
	POTOMAC RIVER.																	RAPPA-HANNOCK RIVER.							MATTA PONI RIVER.		PAMUN-KEY RIVER.	JAMES RIVER.		
	Fort Washington.	Tinkers Creek, near Piscataway.	1 mile N. E. of Piscataway.	Piscataway Creek.	Swan Creek, near Piscataway.	Pomonkey Neck.	Glymont.	1 mile S. E. of Mason Springs.	Mattawoman Creek.	Reedy Run.	Liverpool Point.	Wades Bay.	Clifton Beach.	Aquia Creek.	Potomac Creek.	Paspotansa Creek.	2 miles below Potomac Creek.	1 mile below Massaponax Creek.	3 miles below Massaponax Creek.	1¼ mile above Ware Creek.	Radcliffe's Wharf.	Above Hopyard Wharf.	2½ miles below Hopyard Wharf.	Near Brooke.	Mattaponi River, R. F. and P. R. R. Bridge.	Mattaponi River, first county bridge below R. R.	Pamunkey River, ⅛ mile S. E. of Wickham.	James River, Richmond.	James River, Deep Bottom.	James River, City Point.
Panopea elongata Conrad	*	*	*	*		*	*	*					*	*	*	*	*												*	
Corbula subengonata Dall			*				*	*	*				*				*													
Corbula aldrichi Meyer											*		*	*					*	*										
Corbula oniscus Conrad							*																							
Solen lisbonensis ? Aldrich																														
Tellina virginiana Clark	*	*				*		*					*	*			*													
Tellina williamsi Clark															*															
Tellina papyria ? Conrad	*																													
Tellina subtriangularis																														
Meretrix lenis (Conrad)																														
Meretrix ovata var. ovata (Rogers)																														
Meretrix ovata var. pyga Conrad	*						*	*	?	*	*		*	*	*	*	*		*	*	*		*	*	*			*		
Meetrix subimpressa Conrad																														
Dosiniopsis lenticularis (Rogers)	*		*				*		*	*	*		*	*	*				*					*	*			*		
Protocardia lenis Conrad			*					*						*	*	*	*													
Diplodonta hoppinensis																				*										
Lucina aquiana Clark														*																
Lucina astartiformis Aldrich																														
Lucina dartoni Clark																														
Lucina uhleri Clark			*				*	*	*		*		*		*		*													
Lucina whitei Clark																														
Lucina sp.																				*										
Venericardia planicosta var. regia Con.	*		*	*										*	*	*	*											*		
Venericardia marylandica C. & M.																														
Venericardia potapacoensis C. & M.																														
Crassatellites alaeformis (Conrad)	*		*				*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*							*
Crassatellites aquiana (Clark)							*		*	*	*			*	*															
Crassatellites sp.													*																	
Coralliophaga bryani Clark						*		*																						
Periploma ? sp.																			*											
Pholodamya marylandica Con.	*			*									*	*																
Modiolus marylandicus C. & M.																														
Modiolus alabamensis Ald.	*						*	*			*	*	*	*	*	*	*		*	*	*				*					
Lithophaga marylandica C. & M.													*																	
Anomia marylandica C. & M.													*							*										
Pecten choctavensis Aldrich			*																											
Pecten dalli Clark															*															
Pecten johnsoni Clark															*	*	*													
Pecten sp.															*															
Ostrea sellaeformis Conrad																														
Ostrea compressirostra Say	*	*	*		*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			*	*					*
Ostrea compressirostra var. alepidota Dall	*													*																
Ostrea (Gryphaeostrea) vomer (Morton)				*			*							*	*		*													
Gryphaea vesicularis Lamarck													*																	
Leda parva (Rogers)																														
Leda cultelliformis (Rogers)														*																
Trigonoarca decisa (Con.) *var.*																														
Cucullaea gigantea Conrad	*		*				*	*			*		*	*	*	*	*			*	*	*			*			*		
Pteria limula (Conrad)																														
Glycymeris idoneus (Conrad)			*												*															

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

NANJEMOY FORMATION.

SPECIES.	POTOMAC RIVER.									RAPPAHANNOCK RIVER.				MATTAPONI RIVER.							PAMUNKEY RIVER.		JAMES RIVER.		
	Potomac Creek.	Nanjemoy Creek.	½ mile below Chapel Point.	2½ miles above Popes Creek.	Woodstock. Zone 15.	2 miles above Popes Creek.	1½ mile above Popes Creek.	Popes Creek.	Woodstock. Zones 16 and 17.	Rappahannock River, Hopyard.	1½ mile below Mount Creek.	¾ mile above Port Conway.	2 miles below Port Conway.	Mattaponi River, ½ mile below county bridge to Penola.	½ mile above Burke's Bridge.	3 to 4 miles below Burke's Bridge.	2½ miles below Reedy's Mill Bridge.	1¾ miles below Reedy's Mill Bridge.	2 miles below Marriccossick Creek.	3 miles below Marriccossick Creek.	Pamunkey River, Newcastle.	Pamunkey River, 1 mile east of Newcastle.	James River, Tar Bay.	James River, Evergreen.	James River, Indian Field Point.
Panopea elongata Conrad																									
Corbula subengonata Dall								*	*																
Corbula aldrichi Meyer		*	*	*			*	*	*		*	*	*			*			*		*				
Corbula oniscus Conrad		*		*				*	*																
Solen lisbonensis ? Aldrich			*		*				?																
Tellina virginiana Clark				*				*	*																
Tellina williamsi Clark				*				*	*																
Tellina papyria ? Conrad																									
Tellina subtriangularis												*	*												
Meretrix lenis (Conrad)									*																
Meretrix ovata var. ovata (Rogers)		*	*	*		*		*				*	*						*	*					
Meretrix ovata var. pyga Conrad																									
Meretrix subimpressa Conrad								*	*		*										*				
Dosiniopsis lenticularis (Rogers)																									
Protocardia lenis Conrad								*	*																
Diplodanta hoppinensis																								*	
Lucina aquiana Clark																									
Lucina astartiformis Aldrich																									
Lucina dartoni Clark				*				*	*	*															
Lucina uhleri Clark								*	*																
Lucina whitei Clark			*						*																
Lucina sp.								*																	
Venericardia planicosta var. regia Con.																									
Venericardia marylandica C. & M.				*	?	*		*	?																
Venericardia potapacoensis C. & M.	*	*	*	*		*		*	*		*	*	*					*	*	*	*	*			
Crassatellites alaeformis (Conrad)																									
Crassatellites aquiana (Clark)																									
Crassatellites sp.																									
Coralliophaga bryani Clark																									
Periploma ? sp.					*				?																
Pholadamya marylandica Con.																									
Modiolus marylandicus C. & M.									*																
Modiolus alabamensis Ald.				*				*	*																
Lithophaga marylandica C. & M.																									
Anomia marylandica C. & M.								*	*																
Pecten choctavensis Aldrich				*			*	*																*	
Pecten dalli Clark									*																
Pecten johnsoni Clark									*																
Pecten sp.																									
Ostrea sellaeformis Conrad				*			*	*	*													*	*	*	
Ostrea compressirostra Say																									
Ostrea compressirostra var. alepidota Dall																									
Ostrea (Gryphaeostrea) vomer (Morton)			*																						
Gryphaea vesicularis Lamarck																									
Leda parva (Rogers)				*		*		*	*												*				
Leda cultelliformis (Rogers)				*		*		*	*				*												
Trigonoarca decisa (Con.) *var.*									*																
Cullaea gigantea Conrad								*	*																
Pteria limula (Conrad)								*																	
Glycymeris idoneus (Conrad)								*	*												*	*		*	

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	AQUIA FORMATION.																													
	POTOMAC RIVER.																		RAPPAHANNOCK RIVER.						MATTAPONI RIVER.		PAMUNKEY RIVER.	JAMES RIVER.		
	Fort Washington.	Tinkers Creek, near Piscataway.	1 mile N. E. of Piscataway.	Piscataway Creek.	Swan Creek, near Piscataway.	Pomonkey Neck.	Glymont.	1 mile S. E. of Mason Springs.	Mattawoman Creek.	Reedy Run.	Liverpool Point.	Wades Bay.	Clifton Beach.	Aquia Creek.	Potomac Creek.	Paspotansa Creek.	2 miles below Potomac Creek.	1 mile below Massaponax Creek.	3 miles below Massaponax Creek.	1¼ mile above Ware Creek.	Radcliffe's Wharf.	Above Hopyard Wharf.	2½ miles below Hopyard Wharf.	Near Brooke.	Mattaponi River, R. F. and P. R. R. Bridge.	Mattaponi River, first county bridge below R. R.	Pamunkey River, ⅛ mile S. E. of Wickham.	James River, Richmond.	James River, Deep Bottom.	James River, City Point.
Leda cliftonensis C. & M.											*		*	*	*		*													
Leda tysoni C. & M.																														
Leda parilis (Conrad)																														
Leda improcera (Conrad)																														
Leda parilis var.																														
Leda potomacensis C. & M.																														
Nucula potomacensis C. & M.																														
MOLLUSCOIDEA. Bryozoa.																														
Ceriopora micropora Goldf																														
Lunulites reversa Ulrich																	*													
COELENTERATA.																														
Flabellum sp.														*																
Turbinolia acuticostata Vaughan															*															
Trochocyathus clarkeanus Vaughan			*											*	*															
Paracyathus marylandicus Vaughan			*																											
Eupsammia elaborata (Conrad)								*						*	*															
PROTOZOA.																														
Textularia gramen d'Orbigny			*																											
Nodosaria affinis (d'Orbigny)																														
Nodosaria bacillum Defrance								*									*													
Cristellaria rotatula (Lamarck)								*																						
Cristellaria radiata (Bornemann)																														
Cristellaria gibba d'Orbigny			*																											
Polymorphina austriaca (d'Orbigny)																														
Polymorphina communis d'Orbigny																														
Polymorphina compressa d'Orbigny																														
Polymorphina elegantissima P. & J.																														
Polymorphina gibba d'Orbigny																														
Polymorphina lactea (W. & J.)																														
Polymorphina praelonga Terq.																														
Globigerina bulloides d'Orbigny																														
Discorbina bertheloti (d'Orbigny)																														
Anomalina grosserugosa (Gumbel)			*																											
Truncatulina lobatula (W. & J.)																														
Pulvinulina exigua var. obtusa Bur.			*																											
Pulvinulina schreibersii (d'Orbigny)																														
Nonionina affinis Reuss																														
Amphistegina lessonii d'Orbigny																														
Carpolithus marylandicus Hollick																														
Carpolithus marylandicus var. rugosus H																														

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	Potomac Creek.	Nanjemoy Creek.	½ mile below Chapel Point.	2½ miles above Popes Creek.	Woodstock. Zone 15.	2 miles above Popes Creek.	1½ mile above Popes Creek.	Popes Creek.	Woodstock. Zones 16 and 17.	Rappahannock River, Hopyard.	1½ mile below Mount Creek.	¾ mile above Port Conway.	2 miles below Port Conway.	Mattaponi River, ½ mile below county bridge to Penola.	½ mile above Burke's Bridge.	3 to 4 miles below Burke's Bridge.	2½ miles below Reedy's Mill Bridge.	4¾ miles below Reedy's Mill Bridge.	2 miles below Marriccossick Creek.	3 miles below Marriccossick Creek.	Pamunkey River, Newcastle.	Pamunkey River, 1 mile east of Newcastle.	James River, Tar Bay.	James River, Evergreen.	James River, Indian Field Point.
	NANJEMOY FORMATION. POTOMAC RIVER.									RAPPAHANNOCK RIVER.				MATTAPONI RIVER.							PAMUNKEY RIVER.		JAMES RIVER.		
Leda cliftonensis C. & M.																									
Leda tysoni C. & M.				*				*	*																
Leda parilis (Conrad)																					*				
Leda improcera (Conrad)		*		*				*	*										*						
Leda parilis var.									*																
Leda potomacensis C. & M.			*					*																	
Nucula potomacensis C. & M.		*		*				*	*			*							*		*				
MOLLUSCOIDEA. Bryozoa.																									
Ceriopora micropora Goldf.				*																					
Lunulites reversa Ulrich																									
COELENTERATA.																									
Flabellum sp.									*																
Turbinolia acuticostata Vaughan								*																	
Trochocyathus clarkeanus Vaughan																									
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Anomalina grosserugosa (Gumbel)																									
Truncatulina lobatula (W. & J.)									*																
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Nonionina affinis Reuss									*																
Amphistegina lessonii d'Orbigny									*																
Carpolithus marylandicus Hollick								*																	
Carpolithus marylandicus var. rugosus H.								*																	

MIOCENE.

THE CHESAPEAKE GROUP.

The Miocene deposits of Virginia form part of a broad belt of formations of that age which extend from New Jersey southward to the South Atlantic States. The strata attain considerable thickness and constitute the most important element in the Coastal Plain series with the exception of the Cretaceous beds which are usually thicker than the Miocene although the latter, because of a gentler dip, outcrop over a much wider belt in Virginia and Maryland. In North Carolina, on the other hand, through the removal of much of the Miocene by erosion the underlying Cretaceous beds have a more extensive outcrop.

The materials composing the Miocene formations are largely fine-grained, light-colored sands which are mostly unconsolidated except where locally cemented by carbonate of lime derived from the fossil shells which form such an important feature of the deposits. Diatomaceous earth is also characteristic of the Miocene deposits and occurs in thick beds in its lower portions. A dark blue, often greenish, clay is likewise common in some of the deposits.

It has been found possible, on the basis of the fossils and the lithological characteristics, to divide the Miocene of the Chesapeake Bay region into four formations, known as the Calvert, the Choptank, the St. Mary's, and the Yorktown. These were first grouped together under one formation which was named the Chesapeake formation because of its great development in the Chesapeake Bay drainage basin. The name is now retained as a group name, and very properly, because the four Miocene formations exposed in the region of the Chesapeake Bay form a group of deposits formed under very similar conditions and possessing many striking similarities which distinguish them from the underlying Eocene and the overlying Pliocene (?) and Pleistocene strata. The surface of the Chesapeake group is, for the most part, covered on the divides by deposits of Pleistocene age, but along the estuaries and tributary streams there are many excellent exposures.

Except for the comparatively superficial deposits of the Pleistocene, the Miocene strata are much more widely distributed in the Coastal Plain of Virginia than the strata of any other age. They make their first appearance in the high divides of Stafford County a few miles northeast of Fredericksburg where they overlie the Nanjemoy deposits. From this point they extend in an almost continuous sheet to the south and southeast and

are exposed along almost every stream that has cut through the superficial Pleistocene capping. The most numerous exposures are along the channels of the Potomac, Rappahannock, York, and James rivers. No outcrops of Miocene beds appear on the Bay shore as in Maryland since the bluffs are low and as far as known consist entirely of Quaternary deposits.

The Calvert Formation.

Name.—The basal beds of the Miocene constitute the Calvert formation which receives its name from Calvert County, Maryland, where in the famous Calvert Cliffs are to be seen perhaps the best exposures of the strata of this age anywhere in the Atlantic Coastal Plain. The name was first applied to these deposits by G. B. Shattuck[a] in 1902.

Stratigraphic relations.—The deposits of the Calvert rest unconformably upon the Nanjemoy formation throughout most of the Coastal Plain. In the James River basin, however, this formation transgresses the Nanjemoy and rests on the exposed margins of the Aquia formation while farther south it also transgresses the Aquia and about Petersburg is in contact with the Patuxent beds. Still farther to the south the Miocene at its western margin rests upon the crystalline rocks of the Piedmont Plateau.

The Calvert is unconformably overlain by the Choptank formation in Maryland but whenever exposures of the contact have been found in Virginia the St. Mary's formation succeeds the Calvert unconformably. It is possible, as stated later, that the Choptank formation may overlie the Calvert for a short distance on the south side of the Potomac as on the north side in Maryland but it seems more probable that this formation has already thinned out and disappeared before the south side of the Potomac is reached. It is impossible to definitely determine this point in the absence of an exposed contact in this area due to the cover of Pleistocene deposits.

Lithologic character.—The Calvert formation consists largely of sands, clays, marls, and diatomaceous earth. Fine-grained, light-colored sands predominate. The clays, which usually contain considerable sand, are dark blue to black in color, weathering to a gray or sometimes to a dull white on exposure. They grade into sands through an increase in the arenaceous matter, or into diatomaceous earth due to an increasing number of diatom tests. The blue clay almost invariably contains numerous casts of small shells although at times the original shell substance still remains. Gypsum crystals, sometimes single, at other times arranged in rosettes, are frequently

[a]Science, Vol. xv, 1902, p. 906.

found. The clay also carries at times considerable glauconite, so much that locally it closely resembles the Eocene greensand. Such an occurrence can be seen at the base of the Wilmont bluffs below Port Conway on the Rappahannock River.

Deposits of diatomaceous earth constitute the most striking feature of the Calvert. These consist of countless millions of microscopic siliceous tests of diatoms. They are so small that Ehrenberg estimated that one cubic inch of Bohemian diatomaceous earth contained about 40,000,000 tests. When the diatomaceous earth is pure it is white in color and very light in weight. It, however, contains very frequently considerable argillaceous material and then is apt to be blue in a fresh exposure but whitens by contact with the atmosphere. It is often slightly discolored by the presence of small quantities of hydrous oxide of iron.

The diatomaceous earth beds of the Calvert extend across the states of New Jersey, Delaware, Maryland, and Virginia. They have been penetrated in some of the deep wells at Atlantic City where they have a thickness of about 300 feet. They are well exposed in Maryland at Herring Bay and Pope's Creek. At Wilmont bluffs on the Rappahannock River they have a thickness of about 50 feet in bold, almost vertical cliffs which present an appearance almost as white as chalk when viewed from a distance. Other good exposures are at Carter's Wharf on the Rappahannock River and along Shockoe Creek in the eastern part of Richmond, where a thickness of about 20 feet is shown. The diatomaceous earth also passes frequently under the names of infusorial earth, tripoli, Richmond earth, and Bermuda earth.

Strike, dip and thickness.—The strike of the Calvert formation is parallel to the line of outcrop, namely, north and south, while the beds dip to the east at the rate of about 10 feet to the mile. The thickness of the beds is about 200 feet.

Areal distribution.—The formation makes its appearance in southern New Jersey where it occurs at Shiloh and Jerico, crosses Delaware and Maryland as a gradually widening belt, 10 to 30 miles in width, and continues as far south as Prince George County, Virginia, with a width frequently greater than in Maryland. It is excellently exposed in hundreds of places along the Potomac, Rappahannock, Mattaponi, Pamunkey, James, and Nottoway rivers and their tributaries in the counties of King George, Westmoreland, Essex, Caroline, Hanover, Henrico, King and Queen, King William, New Kent, Charles City, and Prince George. It also occupies small areas in a number of other counties both to the east and to the west of the ones named. In the northern part of this area, particularly in Stafford

County, the Calvert is found some miles to the east of the "fall line" but to the south it extends much farther west and is found lying upon the Piedmont crystallines. Throughout much of the Virginia Coastal Plain outliers of the Lafayette alone extend farther westward.

The Calvert formation occupies the higher-lying lands along the western portions of its area of outcrop with the Eocene and Potomac formations in the lower parts of the valleys and gradually dips to lower and lower levels as it passes to the east, until it finally sinks beneath tide level. The line along which it disappears is in the vicinity of Nomini Bay on the Potomac River and at about the same longitude along the Rappahannock River. It disappears at West Point where the Mattaponi and Pamunkey rivers unite to form York River. From that point the eastern limit takes a southwesterly course to a point a short distance south of Petersburg where it disappears entirely. The formation has not been recognized in Sussex, Greenesville, and Southampton counties. In the first two the St. Mary's is in contact with the crystalline rocks of the Piedmont Plateau.

Paleontologic character.—Fossils are especially abundant in the Calvert strata of Virginia, and represent a wide range of species. As shown in the faunal tables on a later page, fossils belonging to most of the larger groups of animals occur in the Calvert, and certain forms are to be found in almost every place where the formation outcrops. Besides the faunal remains, the Calvert has yielded an abundance of plant fossils. Most of these are microscopic, and belong to the group of the diatoms, but Berry, in 1909, described 14 species of higher plants from the diatomaceous earth of Richmond. About 200 species of diatoms have been described from the diatomaceous earth of Richmond and Petersburg, and careful examination would no doubt reveal the presence of many more.

DETAILED SECTIONS.

The Calvert formation is exposed in hundreds of places throughout its area of outcrop and in almost every case is easily recognized. Most of the sections are along the tributary streams where only a few feet of materials are exposed, while the best are those along the larger streams. The sections given below are typical of the formation and may be duplicated in scores of places throughout the State.

Fig. 1.—Nomini Cliffs, Potomac River. Showing Calvert formation.

Fig. 2.—Section 1½ miles below Bowlers Wharf, Rappahannock River. Showing shell marl of St. Mary's formation.

CALVERT AND ST. MARY'S FORMATIONS.

SECTIONS IN THE POTOMAC RIVER VALLEY.

Along the Potomac River estuary the Calvert formation is finely exhibited in the Nomini Cliffs of Westmoreland County. These rise to a height of 200 feet and are so nearly vertical that it is impossible to scale them in most places. They are the boldest cliffs of the northern Atlantic Coastal Plain and form a striking contrast to the general topography of the region. They consist of Calvert and Pleistocene (Sunderland) materials exclusively. The following five sections give a fair idea of the cliffs.

I. *Section on the Potomac River, three-quarters of a mile southeast of the mouth of Pope Creek.*

			Feet
Miocene.	Calvert	White diatomaceous earth	15

II. *Section of the Nomini Cliffs of the Potomac River, three miles below mouth of Pope Creek.*

			Feet
Pleistocene.	Sunderland	Reddish clay loam	12
		Band of small gravel with reddish clay loam matrix	2
		Reddish clay	4
		Coarse buff sand	4
		Red ferruginous sandstone	3
		Very coarse yellow argillaceous sand not well exposed in lower portion	20
Miocene.	Calvert	Greenish-drab tough plastic clay	21
		Greenish-gray slightly indurated argillaceous sand, rusty where weathered along surface and making a prominent line along bluff. Contains sharks teeth and mammalian bones	1
		Dark greenish-gray very sandy fine-grained clay with a few diatoms	12
		Light greenish-drab sandy clay	7
		Greenish-gray slightly indurated argillaceous sand with shell impressions. Contains shells of *Pecten*, *Melina*, *Ecphora*, etc.	1
		Dark greenish-gray argillaceous sand grading into sandy clay	25
		Greenish-drab more or less arenaceous compact clay, containing diatoms; material light in weight when dry	18
		Total	130

III. *Section of the Nomini Cliffs of the Potomac River, four and one-half miles below mouth of Pope Creek*

			Feet
Pleistocene		Yellowish sands and clays, about............	45-50
Miocene.	Calvert	Greenish-gray clays, sandy clays, and sands, diatomaceous in lower 25 or 30 feet........	65-70
		Total..............................	120

IV. *Section of the Nomini Cliffs of the Potomac River, six miles below mouth of Pope Creek.*

			Feet
Pleistocene		Reddish loam grading down into reddish-yellow and gray sand, with a band of large pebbles and cobbles at base......................	35
Miocene.	Calvert	Greenish-gray, more or less sandy, laminated clay, plastic and tough in upper 8 feet, without fossils	55
		Indurated layer of greenish-gray sandstone, rusty on surface where weathered. Contains casts of *pectens*, etc. This forms a prominent layer which can be traced for a mile or more along the cliff...........	2
		Greenish-gray slightly argillaceous sand full of fossils,—*pectens*, etc.,—most of which are in a soft friable condition..........	10
		Greenish-gray more or less argillaceous sand and sandy clay with several bands containing fossils; diatoms were observed in lower 12 feet...............................	33
		Total..............................	135

This section is very similar to section II although much more fossiliferous in the lower 45 feet. In the above section there is a band of fossils 3 to 5 feet above base, one 12 to 16 feet above base, and one 33 to 43 feet above base.

About one-third of a mile east of section IV the prominent indurated layer indicated in that section at height of 45 feet is at least 60 feet above base, showing that it rises to the east. This means either that the beds beneath rise also or that they gradually thicken. The latter appears to be more probable. Beyond this point to the east the indurated layer loses its characteristics and can no longer be traced.

V. *Section of the Nomini Cliffs of the Potomac River, seven miles below mouth of Pope Creek.*

			Feet
Pleistocene		Reddish-yellow and gray sands, coarse sands, and gravel; indurated corrugated iron stone near base	20
Miocene.	Calvert	Greenish-gray more or less sandy clay	45
		Greenish-gray argillaceous sand slightly indurated. Contains mammalian bones	1
		Greenish-gray argillaceous sand	22
		Fossil band in greenish-gray clay	2
		Greenish-gray sandy clay	11
		Fossil band of greenish-gray argillaceous sand. Fossils especially numerous near base; *Melina* abundant	4
		Greenish-gray sandy clay containing a band of fossils near base; contains diatoms	20
		Total	125

Throughout the entire length of the Nomini Cliffs the beds seem to be almost horizontal. No single bed has been traced throughout the entire cliff section but layers have been traced for a mile or more in different places. The materials in general in sections II and V are about the same. There are certain undulations in the beds but no noticeable dip. In both cases the upper half of the Miocene is almost without fossils. The lower half has several prominent fossil bands at the centre. These continue toward the east but become less prominent in that direction. Diatoms are abundant in the lower 25 or 30 feet throughout the entire length of the cliffs but are less noticeable in the eastern portion. The fossil layer near the base of section IV is perhaps the same as the fossil band 20 to 24 feet above base in section V. Between section V and the extreme east end of the cliffs the beds again descend a few feet.

The fossils for the most part, except a few oysters, barnacles, and many pectens are soft and fragile. Some of the fossil layers in the Nomini Cliffs outcrop for a distance of a mile or more but none extends the entire length of the cliffs. There are very few fossils, if any, in section III. A few were noted in section II. The best place for collecting is between section IV and section V. It is probable that nearly all the beds exposed in the Nomini Cliffs, if perfectly fresh, would be dark green in color. In most places, however, more or less weathering has taken place so that they appear greenish-gray, light green, or even almost white.

SECTIONS ALONG THE TRIBUTARY STREAMS OF THE "NORTHERN NECK."

The belt of land lying between the Potomac and Rappahannock river estuaries and commonly known as the "Northern Neck," topographically consists of a flat dissected upland about 150 to 200 feet in elevation, with narrow terraces separating the central divide from the rivers. In most places the main streams have cut low cliffs in the lower terraces but in a few places the rivers have cut back to the main divide and high cliffs result. The Nomini Cliffs on the Potomac River have already been described. On the Rappahannock, similar cliffs exposing the Calvert deposits occur at Wilmont and near Carter's Wharf.

Along the small streams tributary to the Potomac and Rappahannock rivers in King George, Westmoreland, and Richmond counties, the Calvert formation is exposed in hundreds of places. In general the slopes of the hills are steep and the Calvert is exposed continuously along the sides of the valley. The following sections are characteristic.

Just below mill dam about 1½ miles west of Montross there is an exposure of Calvert argillaceous sand which grades into arenaceous clay. Where unweathered it is bluish-drab; where weathered a light gray. The exposed thickness is about 85 feet. Similar Miocene material is exposed in stream cuttings at several points between Montross and Ethel.

On road between Ethel and Farmers Fork, about one-half mile from Ethel, the road crosses a stream where there is a mill. Just below the dam there is a good exposure of Miocene blue sand about 10 feet in thickness. Upper part is weathered and grayish in color. Above this and poorly exposed in the creek bluff there is a thickness of about 40 feet of Miocene drab clay above which is Pleistocene ferruginous sand containing a few pebble lenses and iron stone layers.

SECTIONS IN THE RAPPAHANNOCK RIVER VALLEY.

The Calvert formation extends along the Rappahannock River for a considerable distance and is exposed in many places. In most places the exposures consist of only a few feet of diatomaceous earth or blue sandy clay outcropping at the base of the low banks which the river has cut in the lower Pleistocene terrace. In certain places, however, the river has cut into the higher lying terrace and high cliffs result in which are excellent exposures of Calvert strata. In general the sections display little variety of material.

On the right bank of the Rappahannock River about 1 mile above the mouth of Mount Creek there is a high cliff though the exposure of strata is not good. Eocene greensand occurs at the base of the section while there is a thickness of at least 50 feet of diatomaceous earth overlying it.

I. *Section, left bank Rappahannock River, one-half mile east of Wilmont Wharf.*

			Feet
Pleistocene		Clay, sand and gravel	20
Miocene.	Calvert	Diatomaceous clay, in places sandy especially near top and varying in the amount of diatoms. Dark green where unweathered but lighter to almost pure white where weathered	94
Eocene.	Nanjemoy	Contact not well exposed. Dark green argillaceous glauconitic sand with casts	6
		Total	120

The purest diatomaceous earth observed is about 15 to 20 feet above the base. The cliff is almost vertical and exposes an excellent section of the Calvert formation.

II. *Section left bank of Rappahannock River, three-quarters of mile east of Wilmont Wharf.*

The section is similar to the one just given except that this is not so well exposed throughout. The contact between the Nanjemoy and Calvert however, is well shown at a small waterfall near the western end of the exposure. It occurs 2½ feet above the water level. There is a sharp change from the dark green glauconitic sand of the Nanjemoy to the light olive green argillaceous sand which forms the base of the diatomaceous clay. Along the contact there are occasional small pebbles ranging in size up to 1½ inches in diameter, forming a basal conglomerate. In a thickness of 3 feet the olive green sand grades up into the diatomaceous clay. The base of the Miocene is evidently formed of the reworked Eocene material.

III. *Section left bank of Rappahannock River, two miles above the mouth of Elmwood Creek.*

			Feet
Pleistocene		Yellow sand and gravel	10
Miocene.	Calvert	Diatomaceous earth and clay originally dark or olive green, now various lighter shades to white on surface. A very pure diatomaceous earth layer occurs at an elevation of 85 feet to 95 feet. The base is not well exposed but a few hundred yards above at a small wharf there is a pure diatomaceous earth layer near the base	110
		Total	120

IV. *Section left bank of Rappahannock River, one-half mile above Carter's Wharf.*

			Feet
Pleistocene		Yellow and red coarse sand and gravel. Pebbles not exceeding a few inches in size. Numerous large boulders	10
Miocene.	Calvert	Pink and white clay	4
		Sand colored, various shades of red, pink, yellow, and gray	25
		Argillaceous sand, dark greenish-gray, where unweathered, light greenish-gray where weathered	32
		Ferruginous fossiliferous sand layer with *Pecten Venus, Dosinia, Turritella,* etc.	6 in.
		Dark green arenaceous clay	10
		Dark green argillaceous sand	9
		Ferruginous fossiliferous sand layer	6
		Dark green clay	5
		Dark green argillaceous sand	22
		Diatomaceous clay, white when dry	18
		Total	141½

The above section resembles very closely the Nomini Cliffs and seems to represent the same horizon. The fossil layers mentioned contain only very decayed fossils. This is principally because the face of the bluff is very much weathered. It is probable that by digging into the fresh material good specimens could be obtained. The purest diatomaceous earth is contained in the lower 18 feet but it is probable that diatoms occur in the layers higher up. Slight differences in the sand and clay content cause the bluff to have a banded appearance. A few large mammalian vertebrae were observed about half way up the bluff. The exposure is a very striking one and furnishes an excellent section of the Rappahannock River Calvert materials.

A series of bluffs not so high or well exposed extends from the preceding section down stream for about 3 miles. The diatomaceous portion may be traced the entire distance with scarcely any variation in level showing that the Miocene beds are very nearly horizontal.

V. *Section right bank of Rappahannock River at Tappahannock.*

			Feet
Pleistocene		Loam grading down into sand with an intermixture of gravel	10-15
		Unconformity	
Miocene.	Calvert	Dark greenish-gray to olive green argillaceous clay, lighter in color where weathered	5-10
		Total	25

VI. *Section right bank of Rappahannock River, one-half mile below Bowler's Wharf and opposite Sharp's Wharf.*

			Feet
Pleistocene		Sand and gravel	20
Miocene.	Calvert	Dark greenish-gray sandy clay full of fossils most of which are well preserved	12
		Total	32

The strata with similar characteristics are exposed for almost a mile along the shore.

VII. *Section right bank of Rappahannock River one-half to one mile below preceding section.*

			Feet
Pleistocene		Yellow sand and sandy clay	14
Miocene.	Calvert	Dark green argillaceous sand full of fossils principally *Arca staminea*, *Venus*, *Fulgur coronatum*, *Turritella plebeia*, *Ostrea*, *Dentalium attenuatum*, numerous small pelecypods, etc.	4
		Greenish-gray, compact clay layer with thin sand laminae	13
		Dark green argillaceous sand or sandy clay with fossils; *Arca staminea*, *Venus*, numerous small pelecypods, etc.	2
		Total	33

The beds rise slightly toward the east and the lower fossil layer was observed to a height of 6 feet about one-half mile below where the section was taken.

SECTIONS ALONG THE MATTAPONI RIVER AND ITS TRIBUTARIES.

The Calvert formation outcrops in many places in the Mattaponi River valley and is remarkably uniform in its lithologic characteristics in the various exposures. Calvert strata are present along the entire course of this stream from near Bowling Green where it enters the Coastal Plain to its junction with the Pamunkey River at West Point. The formation outcrops in the tributary streams in the vicinity of Bowling Green but dips gently to the southeast and for many miles is exposed as a thin band in the low river bluffs lying between the Nanjemoy formation beneath and the Pleistocene above. A few miles above Walkerton the Nanjemoy formation disappears beneath the water level and the Calvert strata occupy all the lower portion of the exposed sections of the river bluffs.

I. *Section below mill dam on Marricossick Creek one mile north of Bowling Green.*

			Feet
Miocene.	Calvert	Light greenish-gray sandy clay	10
		Dark green sandy clay containing casts, especially abundant near base, *Turritella plebeia, Venus*, etc.	8
		Total	18

The top of the section is about on a level with the top of the dam. The base is about 60 feet below the plain on which Bowling Green stands.

II. *Marricossick Creek, at Travers mill, three and one-half miles northeast of Milford.*

Just below the east end of the dam there is a 5-foot exposure of greenish-gray clay containing casts of *Turritella plebeia, Venus, Dosinia*, etc. It belongs to the Calvert formation. In the compact clay in the bed of the stream there are a few small potholes.

III. *Marricossick Creek, Smoot's mill. The dam is on the branch entering the creek just above the mill.*

Just below the north end of the bridge 8 or 10 feet of greenish colored clay are exposed, containing Miocene casts, principally *Turritella plebeia*, and some diatoms. The elevation is a little less than 100 feet above sea level. Below the tail race at the mill similar materials are exposed.

Miocene marl occurs four miles northwest of Walkerton on the farm of G. Murdock, and was formerly dug. Specimens of the marl can be seen about the old marl pit. The shells are so weathered that only *Plicatula, Pecten, Discinisca, Ostrea, Chama*, etc., could be recognized. This marl appears in many small ravines on this and adjoining farms.

In some ravines on the farm of T. M. Barefoot, three miles northeast of Walkerton, great quantities of shell marl have been dug. The marl is not being used at present because of the scarcity of labor. The marl, as exposed, is about 25 feet in thickness. The upper portion is the same bed as described on farm of G. Murdock, consisting of rotten shells forming a lime sand in which *Plicatula* is unusually abundant. Beneath comes yellow and blue (where unweathered) sand in which there is a rather varied fauna with shells preserved.

IV. *Walkerton.*

Just below the mill dam there is a thickness of 17 feet of diatomaceous earth exposed. This lies below the shell marl described as occurring 4 miles northwest and 3 miles northeast of Walkerton. From roadside exposures observed near Walkerton it seems that there is a thickness of perhaps 30 feet of yellow or blue sand between the diatomaceous earth and the shell marl.

V. *Mattaponi River between Walkerton and West Point.*

For several miles below Walkerton the diatomaceous earth appears in the banks frequently showing a thickness of 20 feet. The Pleistocene covering is thin and consists of brown to gray sand with some small pebbles. At White Oak Landing (right bank) the diatomaceous earth is replaced by a blue earth which is intermediate between diatomaceous earth and blue sand. At Mantapike Landing (left bank) the bluff is about 20 feet in height and extends for some distance below. Although largely concealed by vegetation the lower part of the bluff is seen to consist of Miocene buff sand.

At Newington (left bank of river) there is a bluff 18 to 20 feet in height with some Miocene buff sand outcropping at the base. Between Wakema, right bank (Frazier's Ferry), and Indian Town there is a high bluff about 75 feet in height which is said to be the highest bluff on the river. Landslides have obscured part of it but it seems that at least 50 feet consists of Miocene sand which is buff above (where weathered) and blue below. At Courthouse Landing about 2 miles from King and Queen Courthouse the bluff is about 45 feet in height. Blue Miocene earth extends from water to a height of about 5 feet. Between Courthouse Landing and Clifton several low bluffs with blue Miocene earth appear while the exposure at Clifton Landing (left bank) shows the blue Miocene earth very well. Below Clifton Landing no bluffs exposing Miocene were seen on the Mattaponi. A few low bluffs show Pleistocene strata.

VI. *Section along road six and one-half miles southeast of Ashland.*

			Feet
Pleistocene		Surface loam yellow and mottled..........	4
		Band of clay with small pebbles..........	1
		Brown iron sand with some clay..........	5
		Pebble layer (pebbles from 1 to 3 inches in diameter)	1-3 in.
Miocene.	Calvert	Drab clay with many fossil casts, blue when fresh (exposed)........................	10
		Total............................	20¼

SECTIONS IN THE PAMUNKEY AND CHICKAHOMINY RIVER VALLEYS.

There are few good exposures of the Calvert formation along either of these streams due to the low bluffs and the swamps that border the streams throughout so great a portion of their courses. Enough exposures are known, however, to prove the continued distribution of the Calvert along their valleys in Hanover, Henrico, New Kent, and Charles City counties.

At the road crossing of Stony Run, 4½ miles southeast of Ashland, 10 feet of fossiliferous blue clay belonging to the Calvert is exposed resting directly on the crystalline rocks. One mile south of that point at crossing of Ashland-Richmond road and the Chickahominy River similar material about 15 feet in thickness appears on the north side of the stream between the crystalline rock and Pleistocene gravels and sand. On same road 1 mile south of the Chickahominy River the Calvert formation is again exposed.

The Calvert, consisting of drab to blue clay and sandy clay, is exposed in many places along Totopotomy Creek, in the valley of the Chickahominy near Mechanicsville, and near Gaines Mill.

Section in railroad cut and river bank at Ramancoke on the Pamunkey River, four miles west of West Point.

			Feet
Pleistocene		Brown and mottled (red and drab) clay loam interbedded with many layers of coarse sand containing thin bands of pea gravel........	20-25
Miocene.	Calvert	Buff-colored, fine-grained sand with certain portions slightly indurated....................	30-35
		Blue sand containing extremely fragile fossils	25
		Total...........................	85

SECTIONS IN THE JAMES RIVER VALLEY.

The Calvert formation is exposed in few places along the James River though it can be frequently seen along the small tributaries. In Richmond it is exposed in numerous places but best along Shockoe Creek near the Richmond Locomotive Works. It consists of more or less impure diatomaceous earth overlying Eocene greensand and overlain by Pleistocene gravels and loam. The total thickness exposed is 40 to 50 feet. Many species of diatoms have been described from this bed and it contains also some imprints of molluscan shells and vertebrate remains. Most remarkable, however, are leaf remains found in the upper portion.

Mr. E. W. Berry has recently described[a] 14 species of plants from this bed of which 6 are new.

At 18th and Venable Streets in Richmond there is a layer of impure glauconitic sand included in the Calvert drab clay. At its greatest thickness the lenslike layer is 4 feet thick. The glauconite has undoubtedly been derived from the Eocene which outcrops in the vicinity.

At Howlett House Bluff the Calvert is well exposed as given on a preceding page and in several places near Chester. In the main it consists of blue sandy clay with few fossil impressions.

Calvert blue sandy clay overlying Eocene greensand is exposed in many places along Bailey's Creek and on the James River in the vicinity of City Point.

Section on right bank of James River just below Blairs Wharf, eleven and one-half miles below City Point.

			Feet
Pleistocene		Brownish-yellow stratified sand containing small amount of clay in certain layers, also a few thin iron bands and small pebbles.....	19
Miocene.	Calvert	Drab exceedingly tough clay sharply separated from sand above. Clay near base is decidedly blue. No fossils. Exposed to water........	9
		Total........	28

SECTIONS IN THE APPOMATTOX RIVER VALLEY.

The Calvert formation outcrops in many places along the tributaries of the Appomattox River and some of these localities are famous because of the great numbers of fossils present. At Petersburg the formation outcrops in the valley of Lieutenant Run. Diatoms are abundant in certain portions of the bed and have been described by microscopists. Numerous molluscan fossils have also been obtained here as shown by the list given on another page. One of the best sections exposed is the one that follows:

Section in ravine near New Reservoir on Lieutenant Run.

			Feet
Pleistocene		Coarse cross-bedded and laminated buff to ferruginous-brown sand with a rather persistent band of ferruginous sandstone ½ to 1 foot in thickness near base................	15
Miocene.	Calvert	Blue sand containing fossil shells. *Venus tridacnoides* and *Turritella* especially abundant; shells very rotten	5
		Similar blue material without fossils........	8
		Total...............................	28

[a]Jour. Geol., vol. xvii, pp. 19-30.

On Poo Run just east of "The Crater", marl is said to have been dug a great many years ago for fertilizing purposes. Fragments of shells can be picked up in the fields but no exposures of marl can now be seen, although a short distance northeast from "The Crater" nonfossiliferous Miocene buff sand is exposed.

Shell marl belonging to the Calvert formation is found and has been dug at Tinsberry Creek just east of the railroad crossing. It is said to be of a very fine quality for fertilizing purposes as the shells are greatly decayed and disintegrate soon after it is spread on the surface. Thus it acts very quickly. The practice is to use about 250 bushels to the acre if there is considerable vegetation on the land. If not, less is used, otherwise the land would be ruined. Shell marl has also been dug in numerous places on Ashton Creek and its tributaries.

Four miles southwest of Bermuda Hundred yellow ochre was formerly dug. The material was derived from the upper strata of the Calvert formation. The ochre bed is said to be about 7½ feet thick on an average. Specimens of prepared ochre and ochre from a pile near the mouth of one tunnel were seen but none of it can now be observed in place. It was worked by tunnels driven into the hill to a distance of 30 to 35 feet from the surface. Red ochre was manufactured by burning the yellow raw material. It is said to have been more profitable to burn the ochre than to dispose of the natural yellow material.

Shell marl is poorly exposed along Marl Branch three-quarters of a mile southwest of Carson and has been dug for fertilizing purposes along the base of the hill near the branch. The shells occur in a matrix of gray calcareous sand. The following forms were recognized: *Pecten, Venus, Crepidula, Arca, Cardita, Venericardia, Astarte* (2 species), *Glycymeris, Turritella, Crassatellites, Balanus,* worm tube, *Dentalium, Corbula* (?) Bryozoa, etc., etc.

The Choptank Formation.

(NOT RECOGNIZED IN VIRGINIA.)

The Calvert formation is succeeded in Maryland by deposits of sandy clays, sand, and shell marl that are much more arenaceous than the Calvert below or the St. Mary's above. The beds composing this formation decline in thickness toward the Potomac River and are not known with certainty to occur on the southern side of the valley in Virginia. The deposits hitherto described as Choptank in the Nomini Bluffs are now known, from a more exhaustive study of both the stratigraphy and paleontology, to belong

to the Calvert formation. It is possible that the Choptank may be represented, as it gradually thins out, in the low country lying between the known outcrops of the Calvert and St. Mary's formations but buried beneath the cover of Pleistocene formations. No outcrops or well borings occur in this intermediate region and as no evidence is afforded for the presence of the formation it has been considered in the mapping as having finally thinned out north of the Virginia shore of the Potomac.

The St. Mary's Formation.

Name.—This formation receives its name from St. Mary's County, Maryland, where highly fossiliferous beds of this age are found and where the lithologic characters of the formation are also well shown. It was so named by G. B. Shattuck in 1902.[a]

Stratigraphic relations.—The St. Mary's formation overlies the Calvert formation unconformably except in the western portions of Sussex and Southampton counties and the eastern part of Greenesville County, where the St. Mary's rests directly on the crystalline rocks due to its transgression by the Calvert formation. This relation exists in North Carolina where the St. Mary's is the oldest Miocene formation present. Along the Roanoke River it unconformably overlies either the crystalline rocks of the Piedmont Plateau or the strata of the Lower Cretaceous. In the southeastern portion of the State the St. Mary's formation is unconformably overlain by the Yorktown deposits which constitute the latest Miocene formation of the State. In the region of outcrop the St. Mary's, like the Choptank, is frequently concealed from view over the divides and in the valleys of the larger streams by thin deposits of Pleistocene materials which rest unconformably upon the eroded surface of the St. Mary's strata.

Lithologic character.—In lithologic character the St. Mary's formation is very similar to the Calvert except that deposits of diatomaceous earth are lacking. Dark blue to bluish-black compact clay is a very common constituent, while layers of sand and shell marl such as occur in the Choptank formation are of secondary importance. The sands and clays are frequently rich in calcareous matter from the disintegrated molluscan shells. The shell marl has been employed for agricultural purposes in a great many places. In the vicinity of Williamsburg the St. Mary's formation contains considerable glauconitic sand irregularly distributed through the beds of yellow and buff quartz sand. Professor W. B. Rogers described this occur-

[a] Science, Vol. xv, 1902, p. 906.

rence in a letter to the editor of the Farmer's Register dated June 26, 1834, and expressed himself as hopeful that other localities might be found in that region which would furnish as good greensand for fertilizing purposes as that of the New Jersey Cretaceous deposits.

Strike, dip, and thickness.—The strike of the St. Mary's formation is almost due north and south throughout Virginia but north of the Potomac River in Maryland the strike gradually changes to a northeast-southwest direction. The dip of the strata is to the east at about 10 feet to the mile. The maximum thickness of the formation is about 150 feet although this is attained only after the formation disappears beneath the tide, the outcropping portion of the formation being somewhat thinner.

Paleontologic character.—The St. Mary's formation is very rich in fossil remains as in the case of the other Miocene formations, the forms constituting an extremely varied marine fauna, essentially molluscan in character, although containing representatives of nearly all the leading groups of animals from the Protozoa to the Mammalia. The only plants thus far recognized are a few diatoms although there is no doubt but that a careful examination of the sands and clays would show the presence of a large number of diatom species. The St. Mary's formation is found in Westmoreland, Richmond, Northumberland, Lancaster, Middlesex, Gloucester, James City, York, Surrey, Isle of Wight, Nansemond, Sussex, and Southampton counties. Along the Potomac River it appears first in the lower part of Westmoreland County; along the Rappahannock River in the vicinity of Bayport; between the York and James rivers in several stream cuttings west of Williamsburg, and along the James River in many excellent exposures at Dillards Wharf, Claremont, Schmidt's Bluff, etc.; in numerous exposures along the Blackwater and Nottoway rivers in Isle of Wight, Southampton, and Nansemond counties; and in frequent exposures along the Meherrin River both in Virginia and North Carolina.

DETAILED SECTIONS.

SECTIONS EXPOSED IN SMALL STREAMS ON "NORTHERN NECK."

The St. Mary's formation is exposed in numerous places on the peninsula between the Potomac and Rappahannock rivers. The exposures seldom show more than a few feet of Miocene blue sand outcropping beneath the Pleistocene cover.

One-half mile north of Litwalton where the road crosses the stream there is a very good exposure of Pleistocene brown sand about 25 feet in

thickness. The sand contains a great quantity of black grains, principally magnetite. About one-quarter mile farther north near the mill dam the St. Mary's outcrops beneath an ironstone about 1 foot in thickness, forming the base of the Pleistocene, which in this region is 68 feet thick. The Miocene consists of fine buff sand containing many mica flakes.

On the north side of the dam at Chinn's Mill on Lancaster Creek, 3½ miles north of Litwalton sandy drab clay belonging to the St. Mary's formation is exposed.

Section exposed on south side of the mill pond at Union Mills, one mile north of Downings and two miles south of Farnhams.

		Feet
Pleistocene or Recent	Brown sandy loam	
Miocene. St. Mary's	Shell bed consisting principally of *Melina maxillata* with some specimens of *Glycymeris*	8-13 in.
	Brown sand..........................	14-16 in.
	Shell bed principally composed of *Melina maxillata*, some specimens of *Pecten* and *Discinisca*.....................	15 in.
	Sand filled with upright worm tubes....	8 in.
	Shell bed composed of innumerable small Pelcypods, in matrix of sand....about	3
	Total...........................	13⅓

SECTIONS EXPOSED IN RAPPAHANNOCK RIVER VALLEY.

The St. Mary's formation outcrops in many places along the lower course of the Rappahannock River and admirably reveals the lithologic characteristics of the formation. Fossiliferous beds are numerous and have yielded a great variety of species.

I. *Section right bank of Rappahannock River, one-quarter of a mile below Jones Point.*

		Feet
Pleistocene	Red gravelly sand with iron crust at base..	10
Miocene. St. Mary's	Red and yellow sand grading down into greenish-gray sand	24
	Red and yellow sand slightly indurated in places	5
	Yellow and greenish-gray loose sand........	17
	Drab clay thinly interlaminated with sand layers	25
	Greenish-gray fossiliferous sand..........	8
	Total............................	89

Just above Bayport Wharf there is a well exposed cliff about 90 to 100 feet high, showing essentially the same kinds of materials given in preceding section, with the exception of the fossiliferous bed which is wanting. The same prominent laminated clay layer is present but has perhaps dipped a few feet lower than in the section described above.

II. *Section right bank of Rappahannock River one-half mile below Bayport.*

			Feet
Pleistocene		Loam grading into sand and gravel ....about	15
Miocene.	St. Mary's	Greenish-gray sand mottled with yellow..about	15
		Total......................	30

III. *Section right bank of Rappahannock River, one-half mile above Punch Bowl Point, and about two and one-half miles below Bayport.*

			Feet
Pleistocene		Loam grading down into drab clay with a thin band of pebbles at base....................	11
Miocene.	St. Mary's	Greenish-gray argillaceous sand with many fossils, slightly indurated in places near top, the cement being iron oxide. Most numerous species are *Melina maxillata, Arca centeneria*, and *Vermetus virginicus*..........	6
		Total.............................	17

The exposure with essentially the same strata extends for about 200 yards along the shore. The most abundant species of fossils are *Melina maxillata, Arca centenaria, Vermetus virginicus, Ostrea, Turritella variabilis, Panopea goldfussi, Crassatellites turgidulus* (?), *Arca staminea, Pecten madisonius, Ecphora quadricostata, Chione latilirata, Discinisca lugubris, Anomia aculeata.*

IV. *Section right bank of Rappahannock River at Waterview Wharf.*

			Feet
Pleistocene		Sand, clay and loam........................	12
Miocene.	St. Mary's	Greenish-gray sand. An undulating, slightly rusty layer occurs about 3 feet above base containing casts of Miocene shells in a poor state of preservation. In places some of the calcium carbonate remains	6
		Total.............................	18

Along the shores of Urbanna Creek and in the bluff along the river between Urbanna Creek and Nelson's Wharf in West Urbanna the St. Mary's Miocene is exposed. It consists of a buff to gray sand in which there is a bed of shell marl containing a wide variety of molluscan species. The bank

is about 18 feet high of which the upper 3 to 6 feet consists of Talbot sand. The shell layer varies in thickness but is rarely thicker than 2 feet. The sand also carries some shells irregularly distributed through the mass.

V. *Section at Burham's Wharf on the Rappahannock River.*

			Feet
Pleistocene		Brown loamy sand	5½
		Stratified brown and yellow sand with a few pebbles and cobbles (4 inches in diameter) at base	16
Miocene.	St. Mary's	Greenish-gray slightly argillaceous fine sand, blue in color near base, where unweathered, much stained with iron and containing numerous casts and moulds of fossils and a few shells of *Melina maxillata*	15
		Total	36½

SECTIONS EXPOSED IN THE CHICKAHOMINY AND YORK RIVER VALLEYS.

The St. Mary's formation is not well exposed in many places between the Rappahannock and James rivers yet frequently enough to determine its continuity.

I. *Section on left bank of Chickahominy River at Lanexa.*

			Feet
Pleistocene		Reddish-yellow clay (in some places decidedly red and in other places mottled)	10½
		Thinly laminated drab and pink clay separated by thin films of fine sand	11
		Laminated, mottled (pink, drab, and yellow) clay	27
		Greenish-gray clay containing carbonaceous matter	2
Miocene.	St. Mary's	Loose greenish-gray sand	3
		Shell bed, shells in matrix of sand similar to above layer. The shells consist almost entirely of *Pecten eboreus* and *Pecten jeffersonius*. Besides these there are a great many specimens of *Ecphora quadricostata*, *Pecten clintonius*, *Crassatellites*, *Glycymeris*, *Venericardia granulata*, *Astarte*, *Dentalium*, *Discinisca* and *Dosinia*. All except the pectens and ecphoras are exceedingly rotten	3-7
		Light-colored buff to gray sand, few fossils	7
		Blue sand very compact, few fossils (exposed to railroad track)	16
		Total	83½

Near the base of the above section the blue sand contains numerous rounded nodules, many of which look like dumb-bells. Some of these enclose a *Pecten* shell, and are 1½ feet long.

In the old cut just above the shell bed the sand is filled with casts of *Chama* while the upper part of the shell bed is quite firmly indurated in places and some of the shells are filled with calcite crystals. The shell bed here contains besides the fossils already named, *Phacoides, Ostrea, Fissurella*, and *Venus*.

The Pleistocene in the old cut contains near its base in one place a ledge of iron sandstone about 10 inches in thickness. The railroad track is about 25 feet above the river. There is no good exposure but it seems that everything from railroad track to the water consists of loose buff sand.

II. *Section right bank of York River at Mount Folly.*

			Feet
Pleistocene		Brown and mottled loam becoming sandy toward base	15
		Brown sand in places indurated by iron to form quite firm sandstone 10 feet thick	15
Miocene.	St. Mary's	Buff sand containing considerable drab clay	15
		Buff sand containing grains of magnetite	25
		Shell layer containing numerous specimens of *Melina maxillata, Pecten jeffersonius*, var. *septenarius; Ostrea compressirostra;* somewhat indurated	2
		Light-colored buff sand	10
		Greenish-blue fine sand	2
		Total	84

SECTIONS IN THE JAMES RIVER VALLEY.

The St. Mary's formation is well exposed in several places in the James River bluffs where the fossiliferous strata have long been known as excellent collecting grounds.

I. *Section right bank of James River, one and one-quarter miles above Claremont Wharf (just below Old Claremont Wharf).*

			Feet
Pleistocene		Yellow sand with some loam at top and pebble band at base	16
Miocene.	St. Mary's	Shell bed, shells in matrix of yellow sand, forms varied and well preserved	12
		Yellow sand without fossils	15
		Shell layer, shells in matrix of blue sand	10
		Blue sand grading into overlying stratum containing numerous specimens of *Turritella*. Exposed to water	6
		Total	59

II. *Section right bank of James River, just above mouth of Sunken Marsh Creek, two miles below Claremont Wharf.*

			Feet
Pleistocene		Loamy yellow sand with a few thin clay lenses	17
		Bands of small pebbles	$4\frac{1}{3}$
		Cross-bedded sand with many small pebbles and a few rounded cobbles at base	14
Miocene.	St. Mary's	Buff sand	8
		Fossiliferous layer containing many species, of which *Pecten* is by far the most abundant; shells embedded in matrix of yellow sand	11
		Blue clayey sand, slightly fossiliferous	14
		Blue clayey sand, highly fossiliferous with *Turritella* predominating	10
		Blue clayey sand without fossils	5
		Blue clayey sand with fossils distributed through it, *Turritella* abundant, exposed to water	8
		Total	91-$\frac{1}{3}$

One-half to three-quarters of a miles above Dillard's Wharf the upper shell bed described in the previous sections increases in thickness to about 20 feet. The lower shell bed with blue sand matrix remains about the same. Near the wharf a great deal of indurated shell material consisting largely of pectens is strewn on the beach but was not seen in place. In this material a fossil echinoid was found.

III. *Section at Dillard's Wharf on the James River.*

			Feet
Pleistocene.	Talbot	Yellowish-red loam	15
Miocene.	St. Mary's	Shell marl	12
		Light-colored sands with thin strata of shells consisting of *Pecten*, *Venus*, etc	4
		Sandy clay, exposed	5
		Total	36

IV. *Section right bank of James River, eight and one-half miles below Claremont Wharf at Schmidt's Bluff.*

		Feet
Pleistocene	Compact red, yellowish-brown, and mottled (red and yellow) sand, looser at base	17
	White sand with white to mottled (white and pink) clay	8

			Feet
		Band of small pebbles in matrix of white sand containing some white and pink clay.....	4
		Pink to yellow to gray sand containing considerable clay	8
		Sandy yellow to gray clay.................	6
Miocene.	St. Mary's	Layer of indurated shell marl with *Pecten* the dominant genus.....................	5½
		Shell layer............................	20
		Gray sand with few fossils.................	5
		Blue clayey sand slightly fossiliferous (to water)	7
		Total.............................	80½

At Rocky Point, opposite the west end of Jamestown Island, beneath a covering of Pleistocene about 18 to 20 feet in thickness, there is a 12-foot indurated fossiliferous stratum. The shells are firmly consolidated, forming a hard rock which has fallen in great masses and covers the beach. The calcareous material has been removed in some cases forming a porous rock composed of sand molds and casts. *Melina, Pecten eboreus* (?) and *Balanus* are the common forms. Beneath the hard layer there is a bed of loose buff sand containing some fossils. The shell bed seems to represent part of the thicker shell layer described in previous sections while the buff sand represents the blue slightly fossiliferous sand exposed at the preceding localities.

V. *Section right bank of James River just below Scotland Wharf.*

			Feet
Pleistocene		Yellowish-brown sand with some small pebbles	13
Miocene.	St. Mary's	Shell marl, the same layer as that at Rocky Point, though less firmly indurated and not so thick. Fragments of this rock strew the beach. Where the rock is not consolidated the shells are present, but are exceedingly rotten..........................	7
		Buff sand with few fossils..............	2
		Material concealed by wash, to water......	10
		Total..............................	32

In the right bank of the James River, ¾ mile above mouth of Cobham Creek, the Miocene shell bed which is so prominently exposed in the Claremont and Dillard's Wharf bluffs and at Rocky Point and Scotland, outcrops, reaching a height of about 12 feet above the water. Only the lower part of the bed seems to be present and the entire thickness is only about 5 feet. The Pleistocene cover consists almost entirely of sand with few small pebbles and some drab clay. Beneath the shell stratum a little buff sand appears but most

of it is covered by wash. The marked unconformity between the Miocene and Pleistocene is shown one quarter of a mile to the east of this bluff where the Pleistocene extends to the water, the Miocene being cut out. The bluffs are about the same height. In the second bluff the Miocene is probably just below the water as the shells are washed out during storms and thrown on the beach.

SECTIONS IN THE BLACKWATER RIVER VALLEY.

The St. Mary's formation is well developed in the valley of Blackwater River where it contains extensive beds of shell marls which have been dug in many places for fertilizing purposes. The shells occur in a matrix of blue sand or sandy clay and are usually in a good state of preservation. *Mulinia congesta* is especially abundant and in certain layers is practically the only fossil present. Marl pits were visited one-quarter mile southwest of McClelland, one-half mile northwest of Raynor, at Raynor, and 3 miles northwest of Zuni. Numerous other abandoned pits occur in the same region.

I. *Section left bank of Blackwater River at Old Seine Hole Landing, about one and one-quarter miles north of Zuni (by water).*

		Feet
Pleistocene	Sand, yellowish	6
Miocene. St. Mary's	Blue fossiliferous sand weathering to yellow, containing *Crepidula aculeata var. costata, Turritella variabilis, Arca centenaria, Glycymeris subovata, Pecten clintonius, Phacoides anodonta, Plicatula marginata*	6
	Total	12

II. *Section of left bank of Blackwater River, about one-half mile north of Zuni.*

		Feet
Pleistocene	Yellowish sand	6
Miocene. St. Mary's	Yellow to blue sandy marl carrying abundant specimens of *Mulinia congesta*	10
	Total	16

At Zuni in an old well or pit near the pumping station bluish sand and marl were exposed about 4 feet below the surface. *Crucibulum grande, Polynices heros, Turritella variabilis, Mulinia congesta* and *Panopea reflexa* are abundant forms present in the marl.

III. *Section in ravine, about two and one-half miles south of Zuni near old saw mill.*

			Feet
Pleistocene		Yellow and reddish mottled sandy clay......	4-6
Miocene.	St. Mary's	Weathered yellow sandy marl with few or no shells	2-3
		Compact fine-grained sandy and argillaceous marl containing few fossils...............	4-6
		Total............................	15

IV. *Section right bank of Blackwater River, six miles by road south of Zuni.*

			Feet
Pleistocene		Yellowish sand	6
Miocene.	St. Mary's	Yellowish (weathered) sandy marl, fossiliferous	4
		Blue sandy marl, slightly glauconitic, highly fossiliferous	5
		Total..............................	15

V. *Section left bank of Blackwater River, about one and one-half miles below Blackwater Bridge.*

			Feet
Pleistocene		Yellow to white sand......................	6
		Drab sandy clay..........................	6
Miocene.	St. Mary's	Bluish marl containing *Mulinia congesta*	4
		Total..............................	16

Between the above locality and Burdette there are a number of banks which show from 2 to 3 feet of marl similar to that in the foregoing section.

VI. *Section left bank of Blackwater River, about seven miles (by water) south of Zuni.*

			Feet
Pleistocene		Yellowish sand............................	6
Miocene.	St. Mary's	Bluish sandy fossiliferous marl, slightly glauconitic (?) and partially indurated, containing *Cadulus thallus, Dentalium attenuatum, Polynices heros, Turritella variabilis, Arca centenaria, Astarte undulata, Chama congregata, Crassatellites undulatus, Glycymeris subovata. Modiolus ducatelii. Panopea reflexa, Pecten clintonius, P. jeffersonius, Phacoides anodonta, Venericardia granulata*	8
		Total..............................	14

VII. *Section right bank of Blackwater River, seven and one-half miles (by water) south of Zuni.*

			Feet
Pleistocene		Yellow sand	6
Miocene.	St. Mary's	Yellow (weathered) to blue (unweathered) sandy marl carrying numerous specimens of *Mulinia congesta*	3
		Bluish sandy marl, somewhat glauconitic, and highly fossiliferous, containing *Crepidula aculeata* var. *costata, Crucibulum grande, Polynices heros, Turritella variabilis, Arca centenaria, A. incile, Astarte undulata, Glycymeris subovata, Margaritaria abrupta, Ostrea compressirostra, O. sculpturata, Panopea reflexa, Pecten clintonius, P. eboreus, P. jeffersonius, P. jeffersonius* var. *septenarius, Venericardia granulata*	5
		Total	14

VIII. *Section right bank of Blackwater River, eight and one-half miles (by water) below Zuni.*

The bluff at this point is one of the highest along the Blackwater River.

			Feet
Pleistocene		Yellowish sand about	13
Miocene.	St. Mary's	Yellowish weathered sandy marl, fossiliferous, containing *Arca incile, Glycymeris subovata, Mulinia congesta, Ostrea compressirostra, O. sculpturata, Pecten jeffersonius, P. jeffersonius* var. *edgecombensis, Venus rileyi*	20
		Concealed, probably blue marl	12
		Total	45

IX. *Section left bank of Blackwater River about three miles (by water) south of Burdette.*

			Feet
Pleistocene		Yellowish sand	12
Miocene.	St. Mary's	Light blue compact sandy clay weathering to yellow and containing impressions of shells similar to those occurring in upper part of marl beds elsewhere in this region	12-15
		Total	27

A similar section was observed about 1½ to 2 miles (by land) north of Franklin.

X. *Section right bank of Blackwater River at wharf at Franklin.*

			Feet
Pleistocene		Superficial mantle, probably yellow sandy clay	6
Miocene.	St. Mary's	Light olive green compact sandy clay showing fossil impressions and casts of *Mulinia congesta* and *Yoldia laevis*	4-6
		Total	12

A similar section is exposed on the left bank of the Blackwater River about one-eighth mile below the wharf at Franklin.

XI. *Section left bank of Blackwater River, about two and one-half miles below Franklin.*

			Feet
Pleistocene		Yellow sand	2-3
Miocene.	St. Mary's	Blue clay with fossil impressions	2-3
		Total	6

XII. *Section left bank of Blackwater River, two and three-quarter miles below Franklin.*

			Feet
Pleistocene		Buff sand	3
Miocene.	St. Mary's	Drab to yellow sandy clay	4-5
		Weathered blue sandy clay	3
		Total	11

XIII. *Section right bank of Blackwater River, about two and one-half miles below South Quay.*

			Feet
Pleistocene		Yellowish sand	3-4
Miocene.	St. Mary's	Bluish-green weathering to yellow compact sandy clay with fossil impressions	3-4
		Bluish-green compact sandy clay similar to that at Franklin but less weathered, and containing *Mulinia congesta*, and *Yoldia laevis*	4-6
		Total	14

On the left bank of the Blackwater River at Ellis Wharf about four miles below South Quay, Miocene clay is exposed in several places. Occasional exposures of sandy fossiliferous marl occur on either side of the river for several miles below this point.

XIV. *Section left bank of Blackwater River just below Cobbs Wharf, about seven miles below South Quay.*

			Feet
Miocene.	St. Mary's	Yellowish sand	6
		Bluish-green sandy clay, slightly fossiliferous	6
		Total	12

SECTIONS IN THE NOTTOWAY RIVER VALLEY.

Although high bluffs are not common along the Nottoway River yet nevertheless there are numerous exposures of Miocene strata in the comparatively low river banks where the stream has cut through the thin covering of Pleistocene gravels, sands and clays. The St. Mary's is the only Tertiary formation exposed along the Nottoway River. It consists mainly of blue sand or sandy clay in which are occasional lenses of shell marl.

I. *Section in well at lumber mill two miles southeast of Sussex Courthouse.*

			Feet
Miocene.	St. Mary's	Yellowish sand and sandy clay	8-10
		Bluish-green sandy marl	2-4
		Total	14

At the base of Marl Hill, a bluff about 70 feet high on the right bank of the Nottoway River 2½ miles south of Lumberton, there is a good marl bed exposed 15 to 20 feet above the water. The lower portion of this bed is blue in color while the upper weathered part is light yellow.

Yellowish partially indurated sandy marl belonging to the St. Mary's formation outcrops in the right bank of the Nottoway River at Carey's Bridge, about 1½ miles west of Sebrell.

On the right bank of the Nottoway River about 4 miles (air line) above Courtland Bridge, there is a bank 60 feet or more in height, in which the St. Mary's formation is exposed. Marl was dug from the lower part of this bank some years ago but it is now concealed by cliff débris.

On the left bank of the Nottoway River about one-half to three-quarters of a mile above Cypress Bridge, bluish-green sandy marl outcrops about 5 feet above the water. The upper and lower portions of the bluff are concealed by vegetation and talus.

II. *Section west bank of the Nottoway River, about one-eighth mile above Cypress Bridge.*

			Feet
Pleistocene		Yellow sand	5
		Drab laminated clays with yellow sand	10
		Coarse white and yellowish sand	4
Miocene.	St. Mary's	Bluish sandy clay, slightly fossiliferous	1+
		Total	20

At Darden's Mill about 3-¾ miles southwest of Courtland, there is an exposure of blue sandy marl with some glauconite (?) in which are *Venus rileyi, Crassatellites, Pecten, Isocardia, Venericardia granulata, Glycymeris, Astarte, Ostrea, Arca, Chama, Crepidula, Polynices,* etc.

III. *Section right bank of the Nottoway River, about two miles below the S. A. L. Railroad Bridge.*

			Feet
Pleistocene		Reddish brown sand	4-5
Miocene.	St. Mary's	Yellowish to greenish sandy marl, fossiliferous	4-5
		Total	10

IV. *Section left bank of the Nottoway River at Sycamore about 2½ to 3 miles below the S. A. L. Railroad Bridge.*

			Feet
Pleistocene		Buff sandy soil	2
		Reddish yellow sand	3-4
Miocene.	St. Mary's	Dark greenish-gray sandy marl, containing a large number of well-preserved fossils	6
		Total	12

V. *Section left bank of the Nottoway River about one-half mile below Sycamore.*

			Feet
Pleistocene		Drab sandy soil	2
		Coarse white and gray sand	2-4
		Yellow to greenish-yellow sand with an increasing proportion of glauconite grains from the top downward	4-5
Miocene.	St. Mary's	Yellowish-brown to blue sandy marl, glauconitic, and highly fossiliferous, containing *Crepidula aculeata* var. *costata, Dentalium attenuatum, Ecphora quadricostata, Polynices heros, Arca incile, Glycymeris subovata, Mulinia congesta, Ostrea compressirostra, O. sculpturata*	4-5
		Total	16

VI. *Section left bank of Nottoway River about five miles below S. A. L. Railroad Bridge.*

			Feet
Pleistocene		Surface covering, not well exposed............	4
Miocene.	St. Mary's	Blue sandy clay unfossiliferous..............	3-5
		Total..............................	9

SECTIONS IN THE MEHERRIN RIVER VALLEY.

The St. Mary's formation is present in the valley of the Meherrin River from the vicinity of Emporia where the stream enters the Coastal Plain to its junction with the Blackwater River. Good exposures of the underlying strata are rare, however, as the river banks are in most places composed of recent alluvial material. In certain places the river is actively cutting the sides of the valley and Miocene strata outcrop beneath the surficial covering.

In the vicinity of Emporia there seem to be many isolated patches of St. Mary's strata lying between the Piedmont crystalline rocks and the Pleistocene reddish-yellow sands and sandy clays that are so extensively developed in that region. At the mill near Hitchcock shell marl containing *Mulinia congesta, Pecten, Venus, Leda, Polynices, Turritella, Dentalium, Ecphora, Ostrea,* etc., was encountered in two wells at a depth of about 25 feet from the surface. A short distance away granite outcrops showing the Miocene shell marl to be an isolated area deposited in a depression in the irregular surface of the crystalline rock floor. Shell marl was also encountered in a well at the saw mill of J. E. Mayes, $1\frac{1}{2}$ miles north of Emporia. The marl, which contains specimens of *Pecten, Ostrea,* etc., occurs 10 to 12 feet from the surface.

I. *Section on Meherrin River about twelve miles southeast of Emporia (by wagon road).*

			Feet
Pleistocene (?)		Concealed	18 to 20
Miocene.	St. Mary's	Light drab or gray, in places greeenish-gray clay, having very little sand content at top but gradually becoming more sandy and grading into a light gray fossiliferous sand fine in texture. The fossils are present in the form of casts only and are characteristic Miocene species. About 7-9 feet above medium low-water near the base of the bed, the sand is indurated in places so that good specimens were obtained. The following forms were recognized: *Pecten, Dosinia, Fulgur* (?) *Turritella, Leda, Polynices* (?), *Panopea* (?), *Balanus,* etc. about	33
		Total........................ ..	53

In the field above this bluff, where the marl had been used for fertilizing purposes, fragments of *Pecten, Ostrea, Venus,* etc., were observed.

II. *Section on the Meherrin River about one mile above the S. A. L. Railroad Bridge.*

			Feet
Pleistocene		Yellowish loam and sand with a gravel band at base in which are boulders of quartz ranging in size up to 1 foot in diameter.......	10
Miocene.	St. Mary's	Bluish-green plastic clay with fragile fossil casts	2
		Total................................	12

At a point on the Meherrin River about $1\frac{1}{4}$ miles below the S. A. L. Railroad Bridge at a sharp turn where the river cuts against a terrace some 15 feet above water level a marl bed is reported which was covered with water when that section of the river was examined. The marl has been used in the adjoining field and shells of *Pecten, Ostrea,* etc., may be seen scattered about.

III. *Section left bank of Meherrin River about two miles above Branch's Bridge, and about two miles (air line) below the preceding bridge.*

			Feet
Pleistocene (?)		Concealed	10
Miocene.	St. Mary's	Greenish-gray, compact, very fossiliferous sandy clay. The most numerous species is the small pelecypod *Mulinia congesta* common to the Miocene of this region. Many of the forms are very fragile and difficult to preserve. Exposed at high water......................	$4\frac{1}{2}$
		Total..............................	$14\frac{1}{2}$

At the next cove on the right about one-half mile below the preceding the same bed is exposed in a similar bluff. A few forms not observed in the preceding section were noted. This place is about 1 mile (by water) above Branch's Bridge.

At Branch's Bridge which is about half way between the upper and lower S. A. L. Railroad bridges about 5 feet of rather dark greenish-gray sandy clay filled with fossils is exposed. The horizon is about the same as at the preceding localities and the material is similar.

IV. *Section on Meherrin River about one and one-half miles below Branch's Bridge.*

		Feet
Pleistocene	Concealed	10
	Gray to yellow ferruginous sand, argillaceous at top, becoming coarse and gravelly below with pebbles ranging in size up to 1 inch in diameter. One layer is made up of pebbles about the size of peas. This is streaked with pink and yellow. The whole is poorly exposed	15
Miocene. St. Mary's	Light drab to almost black clay, somewhat laminated, the laminae due to fine sand partings, the whole more or less weathered, and showing occasional pink and yellow colors	11
	Dark green slightly arenaceous clay, very compact and plastic; barren of fossils	13
	Similar material containing characteristic Miocene fossils	22
	Total	71

This bluff is not very well exposed, because of landslides. The principal fossil found is the small pelecypod, *Mulinia congesta,* so characteristic of the Miocene of this region. Other forms present are *Turritella, Pecten, Ostrea, Dosinia,* etc.

On the left bank of the Meherrin River about 3 or 4 miles above the lower S. A. L. Railroad Bridge, four feet of greenish-blue sandy clay full of shells is exposed. The species present are the same as at Branch's Bridge.

V. *Section on the Meherrin River about three-quarters mile above the lower S. A. L. Railroad Bridge.*

		Feet
Pleistocene (?)	Concealed	25
Miocene. St. Mary's	Reddish loamy clay	10
	Yellow fossiliferous sand, the principal shell being the small characteristic Miocene pelecypod *Mulinia congesta,* with a few *Pecten, Ostrea, Balanus,* etc	7
	Drab sandy clay	2
	Concealed	2
	Very rotten sandy shell marl, with *Pecten, Ostrea, Venericardia, Crepidula, Balanus,* etc	5
	Total	51

A few hundred yards below the above locality there is a better exposure of the marl. The material is less weathered and the matrix consists of the usual dark green argillaceous sand.

VI. *Section on the Meherrin River a few hundred yards below preceding section.*

			Feet
Pleistocene		Reddish yellow sandy clay and sand, laminated ....about	20
		Light gray or drab sandy clay mottled red with iron..............................	10
Miocene.	St. Mary's	Dark green sandy clay yellow in places, due to weathering, full of *Mulinia congesta* with a few other forms, *Pecten, Crepidula*, etc. ....about	36
		Similar material with many fossils. To water's edge.............................	5
		Total.................................	71

The Yorktown Formation.

Name.—The Yorktown formation has been so named because of the excellent exposure of the strata of this age in the prominent cliffs at Yorktown. The name was first employed in a formational sense by Clark and Miller[a] in 1906.

Stratigraphic relations.—The Yorktown formation overlies the St. Mary's formation conformably, although more careful work may reveal the presence of a slight unconformity. Such a break would help to explain the striking changes in physical environment between the two epochs of sedimentation as shown in the lithologic character of the strata. The Yorktown is for the most part concealed from view over the divides as well as in many of the larger valleys by unconformably overlying deposits of Pleistocene age.

Lithologic character.—The most characteristic materials of the Yorktown formation are beds of comminuted shells in which are contained numerous shells still entire but often more or less worn. These fragmental beds are well exposed along the York River below Yorktown at Fergussons Wharf, at Smithfield, at Benn's Church, at Suffolk, and near Reid's Ferry. They are usually quite firmly indurated by calcium carbonate obtained from the same or overlying marl beds. The appearance of the rock is not unlike the coquina

[a]Clay Deposits of the Virginia Coastal Plain. Geol. Series, Bull. No. 11, Geol. Survey of Virginia, 1906, p. 19.

rock of Florida, and doubtless the two have had a similar origin. The shell fragments are of various sizes and are mixed with greater or less amounts of sand, the materials closely resembling the modern beach shell deposits of the West Indies. It is probable that these fragmental layers accumulated in very shallow waters, the breaking and wearing of the shells being accomplished by the shore waves. In addition to these fragmental shell beds the Yorktown formation contains layers of sand, blue sandy clay, and also beds in which the shells are excellently preserved. Occasional grains of glauconitic sand are distributed through the beds of light-colored quartz sand. Since the formation of the Yorktown beds there has been considerable removal of the calcareous material by percolating waters, accompanied by a sinking of the overlying beds in many places, with the production of apparent unconformities. Occasionally the calcium carbonate removed from the upper beds has been deposited in the form of calcite crystals in the cavities of the shells of lower beds. Thus in many places nearly perfect internal casts of *Venus mercenaria* and other forms can be found composed of pure calcite.

Strike, dip, and thickness.—The strike of the Yorktown formation is in a north and south direction, while the normal dip of the beds is toward the east at the rate of a few feet to the mile. Locally, however, as seen especially at certain points in the Yorktown cliffs, the beds are horizontal or have a slight dip to the west. The shallow-water origin of the Yorktown beds accounts for the greater variability in comparison with the other Miocene formations which were for the most part accumulated in much deeper and more quiet waters. The thickness of the Yorktown formation is approximately 125 feet.

Paleontologic character.—As shown in the following sections the Yorktown formation contains a very rich and varied fauna. It is one of the most fossiliferous formations represented in the entire series of Atlantic Coastal Plain sediments and for years the beds exposed at Yorktown have been favorite collecting grounds for workers in Tertiary geology. While the fauna is distinctly molluscan in character, yet numerous vertebrate bones may be collected along the cliffs at almost any time. The recent discovery of the lower jaw of a walrus[a] in these beds is of especial interest.

Areal distribution.—The formation outcrops in Gloucester, James City, York, Warwick, Isle of Wight, and Nansemond counties. It has not been recognized in Maryland but may be present beneath the covering of Pleisto-

[a]Edward W. Berry and William K. Gregory. Amer. Jour. Sci., 4th ser., Vol. xxi, pp. 444-450, figs. 1-4, 1906.

cene materials on the Eastern Shores of both Maryland and Virginia. It is well exposed at Yorktown on the York River, at Smithfield on a tributary of the James River, and in the vicinity of Suffolk. The prevailing low topography in the region of outcrop of the Yorktown formation results in fewer exposures than in the case of the other Miocene formations. The formation has been traced southward into North Carolina where it is exposed in numerous places along the Chowan River and its tributaries.

DETAILED SECTIONS.

The Yorktown formation is well developed in the southeastern portion of the State in a belt extending southward from Gloucester County to the North Carolina line. In this region outcrops are numerous along many of the streams although only along the large estuaries can thick sections be observed. Fragmental shell beds which constitute the most distinctive lithologic features of the formation and distinguish it from any of the other Miocene formations of this region, outcrop in many places.

SECTIONS IN THE YORK RIVER VALLEY.

The Yorktown formation has its typical development in the region of Yorktown where extremely fossiliferous strata in the high bluffs have long been known to contain a great variety of well preserved fossils. No other locality in the State has furnished so many species or has received so much attention from paleontologists. The beds that outcrop in the vicinity of Yorktown extend through the adjoining counties and are exposed along many of the small streams.

At Stubb's Pond 1¼ miles northwest of Sassafras there is an exposure of about 8 feet of shell marl consisting principally of *Pecten jeffersonius* with numerous specimens of *Arca, Ostrea, Venus, Ecphora*, etc. The marl is overlain by about 30 feet of Pleistocene strata, the lower portion of which is rather sandy and contains some small pebbles but grades upward into a mottled red and drab clay.

On the valley slope of Poplar Spring Branch in Gloucester County there are poor exposures of Pleistocene and Yorktown materials. The lower 35 to 40 feet consists of drab clay and buff-colored Miocene (Yorktown) sand, the upper 30 feet of Pleistocene material similar to that described in the preceding note.

One-quarter mile north of Money a shell layer about 8 feet thick outcrops near stream.

Cliff near Yorktown, York River. Showing indurated calcareous beds of the Yorktown formation.

INDURATED CALCAREOUS BEDS OF YORKTOWN FORMATION.

Two and one-half miles southwest of Money shell marl about 10 feet in thickness is exposed along the roadside. *Chama congregata* is by far the most abundant fossil.

Three-quarters of a mile northwest of Clopton, a layer of shell marl outcrops along Carter's Creek just below the dam. In the vicinity of Gloucester Point there is considerable marl which before the war was used extensively on land, but little has been dug since then. At Bellefield on the south side of the river the same is true.

At the road crossing of Scimmino Creek mottled Pleistocene sand and clay about 30 feet in thickness overlies about 25 feet of Miocene (Yorktown) gray, iron-brown, and buff-colored sands in definite layers. In certain bands there is considerable clay present.

At the road crossing of Queen and Carter's creeks Miocene buff-colored sand containing fossils is exposed in the bottom of the valleys. The overlying Pleistocene is about 25-30 feet in thickness and consists of mottled (red, brown, and drab) clay grading downward into a cross-bedded sand.

At the road crossing near the head waters of King Creek, a shell layer 15 to 20 feet in thickness is poorly exposed along the roadside. The great quantity of *Pecten jeffersonius* and a few fragments of *Pecten clintonius* indicate that this layer is the same as that seen at the upper part of Bellefield and 1 mile below King's Mill on the James River. Some large species of *Cardium* were seen. Among the species represented at this locality are the following: *Arca centenaria, A. incile, Astarte concentrica, A. symmetrica, A. thisphilla* ?, *A. undulata, Cardita arata, Chama congregata, Crassatellites undulatus, Glycymeris subovata, Ostrea compressirostra, Pecten jeffersonius, P. madisonius, Phacoides anodonta, Venus rileyi, Crucibulum grande, Turritella variabilis.*

On Black Swamp Creek there is a shell layer exposed, consisting principally of casts, with some decayed shells. It resembles the layer occurring near the west end of Bellefield bluff.

Section exposed along the right bank of York River from King's Creek to Wormley's Creek.

			Feet
Miocene.	Yorktown	Sandy gray shell marl: shells generally large bivalves badly worn, sometimes fragmentary. Contains *Crepidula spinosa, Ostrea*, perhaps *O. virginica*; at Bellefield, *Melina maxillata, Pecten jeffersonius, P. clintonius, Glycymeris subovata, Venus tridacnoides, V. rileyi*, etc..	10
		Gray marl full of shells in some places becoming fragmentary: contains *Arca incile, Car-*	

	Feet
dita, Venus rileyi Ostrea sculpturata, Diplodonta elevata (?), *Glycymeris subovata, Dosinia acetabulum, Pecten jeffersonius*	14
Gray sandy and clayey marl. Contains *Crepidula, Venus*, etc., few and poorly preserved	14
Blue sandy clay becoming marly and stained brown by iron oxide. Contains *Yoldia lævis* (?), *Cytherea sayana, Pandora crassidens, Spisula delumbis, Dosinia acetabulum, Ensis, Scaphella, Dentalium dentale* (?)	12
Sandy marl with numerous shells that in some portions are finely comminuted and cemented together by calcium carbonate forming a fragmentary rock; contains *Pecten jeffersonius, Venus rileyi, Glycymeris subovata, Delphinula, Arca incile, Ostrea compressirostra, Chama corticosa, Plicatula marginata, Raeta, Pholadomya abrapta, Panopea reflexa, Lucinae, Tellinae, Astarte limulata*	27
Blue sandy clay sometimes stained brown by iron oxide; contains *Tellinae, Spisula delumbis, Yoldia lævis, Pandora crassidens*	5
Sandy gray marl rendered somewhat hard by the calcium carbonate from *Crepidulae* that form the most of the bed; contains *Crepidula spinosa, Arca centenaria, A. incile, Chama corticosa, Ostrea compressirostra, Pecten jeffersonius, Balanus proteus*	13
Soft yellowish-gray sandy marl. Contains *Crepidula*, though not so abundant as in layers above or below	12
Soft yellowish-gray sandy marl grading into a blue clayey arenaceous marl; contains *Crepidula, Callocardia sayana, Turritella alticostata*	12
Total	119

The above section was prepared by G. D. Harris, who made a careful study of the Yorktown cliffs for Dr. Dall. The lowest member is exposed about 2 miles below Yorktown and the highest outcrops near Indian Field Creek.

SECTIONS IN THE JAMES RIVER VALLEY.

Because of the James River being bordered by low land throughout a large part of its lower course outcrops of Tertiary strata appear in few places. However, in certain localities bluffs that are now being cut by the waves of the estuary furnish admirable exposures for study and for the collection of fossils.

South of the James River in Nansemond County there are numerous exposures, especially in the vicinity of Smithfield and Suffolk.

I. *Section one mile east of King's Mill, left bank of James River.*

			Feet
Pleistocene		Yellow loam becoming sandy below..........	20
Miocene.	Yorktown	Yellow sand............................	15
		Shell layer in sandy matrix in which *Panopea* predominates......................	4
		Sandy clay layer, few shells.............	4½
		Shell layer composed almost entirely of *Chama congregata*	8
		Sandy clay layer containing fewer shells..	8
		Layer composed mainly of *Pecten jeffersonius*, very compact..................	4
		Loose sandy layer containing many small shells and *Pecten clintonius* (exposed)..	6
		Total.............................	69½

On Blow's Mill Run, one and one-half miles northwest of Lee Hall, there is a shell layer 10 feet thick exposed about 15 feet above the creek. It contains a great variety of molluscan fossils.

II. *Section right bank of James River at Fergusson's Wharf.*

			Feet
Pleistocene (?)		Concealed by vegetation	20
Miocene.	Yorktown	Fragmental shell mass quite thoroughly indurated, sharply separated from the layer beneath.........................	15
		Blue sandy clay, few fossils...............	17
		Bed of fossils, in material, similar to above layer; *Chama congregata* especially abundant (exposed to water)..........	4½
		Total..............................	56½

III. *Section south bank of James River at Morgart's, five miles north of Smithfield.*

			Feet
		Pale yellow sandy loam	2
Pleistocene		Reddish-yellow sandy clay	2-4
Miocene.	Yorktown	Yellowish calcareous highly fossiliferous marl, in some portions material loose, in others firmly indurated by calcareous cement. There is a well-defined horizontal line but no unconformity between this layer and the succeeding.....................	3-5
		Yellowish sandy marl, with numerous casts and some decomposed shells; similar to those in following layer; *Chama*, *Crepidula*, etc. especially abundant............	2-3

			Feet
		Yellow weathered sandy marl carrying the same fossils as the layer beneath and gradually passing into it	5-8
		Greenish-blue compact sandy marl with some clay, bearing numerous fossils, among them *Ostrea, Turritella, Cardium, Dosinia, Glycymeris, Panopea, Dentalium, Ecphora*	12-15
		Total	37

Indurated shell marl containing an abundant fauna in an excellent state of preservation, is well exposed at and near Smithfield on Pagan Creek and many important collections of fossils have been made at this place.

IV. *Section in marl pit near spring just north of Benn's Church.*

			Feet
Pleistocene		Gray sandy loam	2
		Yellow sands with some argillaceous material toward base	3-6
		Unconformity.	
Miocene.	Yorktown	Thick bed of yellow calcareous marl composed of comminuted shells of varying degrees of fineness becoming coarser toward the base of the bed	12
		Total	20

V. *Section in marl pit along stream one-quarter mile below Benn's Church.*

			Feet
Miocene.	Yorktown	Yellowish sand	4-6
		Yellowish marl similar to that described in the preceding section	6-8
		Total	14

About ¾ mile west from Benn's Church, near an abandoned mill dam on a small creek similar indurated marl is exposed.

VI. *Section in S. G. Webb's marl pit one-quarter mile north of Chuckatuck on creek about one-quarter mile below dam.*

			Feet
Pleistocene		Yellow sand	3-5
Miocene.	Yorktown	Finely comminuted shells and small forms in matrix of horizontally stratified yellow sand	3
		Alternating layers of shells and sandy marl; the following forms were noted: *Pecten, Dosinia, Glycymeris, Arca, Turritella*, and *Ephora quadricostata*	5+
		Total	13

VII. *Section at Chuckatuck, just below mill dam.*

			Feet
Pleistocene		Gray and yellow sands with numerous small gravel and with occasional indurated layers about	20
		Concealed from view	10
Miocene.	Yorktown	Olive green argillaceous marl with some sand, carrying only a few fossils, chiefly *Pecten*, *Melina*, *Cardium*, *Glycymeris*, and *Echinocardium orthonotum*	5
		Total	35

VIII. *Section along roadside near Everet's Creek one-quarter mile east of Everet's Bridge.*

			Feet
Pleistocene		Yellow to gray laminated sand somewhat argillaceous in places and containing an almost continuous band of pebbles at base	5
Miocene.	Yorktown	Fine buff to gray sand, blue where unweathered (expcsed)	8
		Total	13

Farther down the hill near the bridge shell marl outcrops beneath 3 feet of yellow sand. The shells, for the most part well preserved, are in a matrix of yellow sand. *Turritella* and *Corbula* (?) are especially abundant.

IX. *Section along roadside just south of Exit Post-Office.*

			Feet
Pleistocene		Hard laminated buff sand with some pebbles at base	9
Miocene.	Yorktown	Shell marl; fossils, many perfect, contained in a matrix composed of fragmental shells and sand, partially indurated at base. This marl has been dug for fertilizing purposes (exposed)	6
		Gap due to concealment by vegetation	5
	St. Mary's	Just below dam, blue sand containing many small Pelecypods, *Cadulus*, *Polynices*, etc., (exposed)	6
		Total	26

At the bridge, there is an exposure of this blue sand about 12 feet thick which contains a considerable variety of entire shells.

Much marl is found about Western Branch, Nansemond River, near Reid's Ferry. The shells are in matrix of broken shells much resembling the material at Yorktown.

X. *Section on east side of Nansemond River, about one mile south of Reid's Ferry Post-Office.*

			Feet	Inches
Pleistocene		Surface loam		8
		Laminated drab clay		4
Miocene.	Yorktown	Gray sand	3	
		Yellow loamy sand with impressions of fossils	1	6
		Fragmental shell marl, composed almost entirely of small shell fragments with very few perfect shells, except some exceedingly small species. A few pectens, probably *Pecten eborcus* were seen. The marl has been dug on this farm for use on peanut fields (exposed)	3	
		Total	8½	

XI. *Section in marl pit on Brigg's Creek, about six miles northwest of Suffolk.*

			Feet
Miocene.	Yorktown	Yellow marl made up of broken fragments of shells	6
		Yellow marl, sandy with numerous well preserved shells such as *Panopea, Urosalpinx, Ostrea, Pecten, Balanus,* etc	3
		Total	9

XII. *Section on Calhoun Creek, about three miles northwest of Suffolk at Calhoun Bridge.*

			Feet
Pleistocene		Yellow sands	6-10
		White sands, fine-grained, cross-bedded	4-6
Miocene.	Yorktown	Blue sandy compact marl highly fossiliferous	12-15
		Total	31

On the south side of the creek, a short distance below the bridge there is a steep bank showing a slightly different section.

XIII. *Section on Calhoun Creek three miles northwest of Suffolk.*

			Feet
Pleistocene		Yellow sands with coarse gravel	10-15
Miocene.	Yorktown	Yellow sandy marl, fossiliferous	10-15
		Blue sandy marl, similar to above, fossiliferous	3-5
		Total	35

TABLE SHOWING DISTRIBUTION OF MIOCENE FAUNA.

Species.	Calvert Formation.							St. Mary's Formation.															
	Pot. River.	Rap. River.	Mat. River.	James River.			App. River.	Rappahannock River.					Chick. River.	James River.				Blackwater River.		Nottoway River.		Meherrin River.	
	Nomini Cliffs.	Carter's Wharf.	Walkerton.	Richmond.	City Point.	Bailey's Creek.	Petersburg.	Bowler's Wharf.	Farnham—2½ mi. south.	Jones Point—¼ mi. below.	Bayport—2½ mi. below.	Urbanna.	Lanexa.	Claremont Wharf.	Sunken Marsh Creek.	Dillard's Wharf.	Cobham Bay.	Zuni.	South Quay—2 mi. below.	Delaware Park.	Sycamore.	Maddelys Bluff.	Branch's Bridge.
Mammalia.																							
Delphinodon venustus Leidy				*																			
Ixacanthus conradi (Leidy)																							
Physeter vetus Leidy																							
Orycterocetus quadratidens Leidy																							
Cetotherium leptocentrum Cope																							
Siphonocetus expansus Cope																							
Siphonocetus priscus Leidy																							
Mesocetus siphunculus Cope																							
Rhegnopsis palaeatlanticus (Leidy)					*																		
Thinotherium annulatum Cope																							
Procamelus virginiensis Leidy																							
Prorosmerus alleni Berry & Gregory																							
Phoca wymani Leidy				*																			
Reptilia.																							
Syllomuscris patus Cope																							
Thecachampsa (?) antiqua (Leidy)	*																						
Pisces.																							
Hemipristus serra Agassiz																							
Dosyatus sp. indet				*																			
Protautoga conideus Leidy																							
Pogonias multidentatus Cope																							
Arthropoda.																							
Cancroidea	*																	*			*	*	
Balanus concavus Brown	*					*		*	*	*					*		*	*	*	*	*	*	*
Mollusca. Gastropoda.																							
Tornatina canaliculata Say							*																
Terebra dislocata Say																							
Conus diluvianus Green																							
Drillia limatula Conrad																						*	
Drillia lunata Lea							*																
Oliva litterata Lamarck												*						*			*		
Olivella mutica Say																							
Marginella limatula Conrad																							
Marginella bella Conrad																							
Scaphella obtusa Emmons																					*		
Scaphella mutabilis Conrad												*						*			*		
Fasciolaria rhomboidea Rogers																	*						
Fulgur spiniger Conrad																							
Fulgur pyrum var. incile Conrad																					*		
Fulgur coronatum Conrad								*															
Fulgur maximum Conrad																							
Fulgur perversum Linné																							
Ecphora quadricosta Say	*		*			*		*	*			*		*	*	*					*	*	
Ptychosalpinx altilis Conrad																							
Ptychosalpinx laqueatum Conrad							*																
Ptychosalpinx multirugatus Conrad																							
Ilyanassa porcina Say							*																
Ilyanassa isogramma Dall																							
Ilyanassa obsoleta Say																							

TABLE SHOWING DISTRIBUTION OF MIOCENE FAUNA.

	Yorktown Formation.											Miscellaneous.				
	York River.				James River.			Nansemond River.								
Species.	Williamsburg—2 mi. north.	Bellefield.	Yorktown.	King's Mill.	Ferguson's Wharf.	Smithfield.	Benn's Church.	Chuckatuck.	Exit.	Reid's Ferry—1½ mi. S. E.	Suffolk.	Westmoreland County.	Stafford County.	Pamunkey River.	James River.	Virginia.
Mammalia.																
Delphinodon venustus Leidy	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Ixacanthus conradi (Leidy)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*
Physeter vetus Leidy	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*
Orycterocetus quadratidens Leidy	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*
Cetotherium leptocentrum Cope	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...
Siphonocetus expansus Cope	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...
Siphonocetus priscus Leidy	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...
Mesocetus siphunculus Cope	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...
Rhegnopsis palaeatlanticus (Leidy)	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Thinotherium annulatum Cope	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...
Procamelus virginiensis Leidy	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*
Prorosmerus alleni Berry & Gregory	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Phoca wymani Leidy	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Reptilia.																
Syllomuscris patus Cope	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...
Thecachampsa (?) antiqua (Leidy)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Pisces.																
Hemipristus serra Agassiz	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*
Dosyatus sp. indet	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Protautoga conideus Leidy	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*
Pogonias multidentatus Cope	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*
Arthropoda.																
Cancroidea	...	...	*	...	...	*	...	...	...	*	*	...	...	...	...	...
Balanus cancarus Brown	...	...	*	...	...	*	*	*	...	*	*	...	...	...	...	...
Mollusca. Gastropoda.																
Tornatina canaliculata Say	...	...	...	...	*	...	...	*	...	...	*	...	...	...	...	...
Terebra dislocata Say	...	...	...	...	...	*	...	...	...	...	*	...	...	...	...	...
Conus diluvianus Green	...	...	*	...	...	...	...	*	...	...	...	...	...	...	...	...
Drillia limatula Conrad	...	...	*	...	...	*	...	...	...	...	*	...	...	...	...	...
Drillia lunata Lea	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Oliva litterata Lamarck	...	*	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Olivella mutica Say	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Marginella limatula Conrad	...	...	*	...	...	...	*	...	...	...	*	...	...	...	...	...
Marginella bella Conrad	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Scaphella obtusa Emmons	...	...	...	...	...	*	...	...	...	...	...	...	...	...	...	...
Scaphella mutabilis Conrad	...	...	...	...	...	*	...	*	...	...	*	...	...	...	...	...
Fasciolaria rhomboidea Rogers	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Fulgur spiniger Conrad	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...
Fulgur pyrum var. incile Conrad	...	...	*	...	*	...	...	...	...	...	*	...	...	...	...	...
Fulgur coronatum Conrad	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...
Fulgur maximum Conrad	...	...	*	...	...	*	...	...	...	...	*	...	...	...	...	...
Fulgur perversum Linné	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Ecphora quadricosta Say	...	*	*	...	...	*	...	*	*	...	*	...	...	...	...	...
Ptychosalpinx altilis Conrad	...	...	*	...	...	...	...	...	...	...	*	...	...	...	...	...
Ptychosalpinx laqueatum Conrad	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Ptychosalpinx multirugatus Conrad	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Ilyanassa porcina Say	...	*	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Ilyanassa isogramma Dall	...	*	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Ilyanassa obsoleta Say	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...	...

TABLE SHOWING DISTRIBUTION OF MIOCENE FAUNA.

SPECIES.	CALVERT FORMATION.							ST. MARY'S FORMATION.															
	POT. RIVER.	RAP. RIVER.	MAT. RIVER.	JAMES RIVER.			APP. RIVER.	RAPPAHANNOCK RIVER.					CHICK. RIVER.	JAMES RIVER.				BLACKWATER RIVER.		NOTTOWAY RIVER.		MEHERRIN RIVER.	
	Nomini Cliffs.	Carter's Wharf.	Walkerton.	Richmond.	City Point.	Bailey's Creek.	Petersburg.	Bowler's Wharf.	Farnham—2½ mi. south.	Jones Point—¼ mi. below.	Bayport—2½ mi. below.	Urbanna.	Lancxa.	Claremont Wharf.	Sunken Marsh Creek.	Dillard's Wharf.	Cobham Bay.	Zuni.	South Quay—2 mi. below.	Delaware Park.	Sycamore.	Maddelys Bluff.	Branch's Bridge.
Ilyanassa granifera Conrad																							
Nassa bidentata Emmons								*										*					
Nassa harpuloides Conrad																							
Anachis harrisii Dall																							
Murex umbrifer Conrad																							
Eupleura caudata Say																							
Scalaspira strumosa Conrad								*													*	*	*
Urosalpinx trossulus Conrad																							
Coralliophila lepidota Dall																							
Scala sayana Dall																							
Scala lineata Say																							
Niso lineata Conrad																							
Triforis melanura C. B. Adams							*																
Seila adamsi H. C. Lea																					*		
Caecum stevensoni Meyer																							
Caecum virginianum Meyer																							
Serpulorbis granifera Say					*				*			*		*	*			*			*		*
Vermetus sculpturatus H. C. Lea							*																*
Vermetus virginica Conrad												*											
Turritella indenta var. bipartita Conrad	*						*	*			*												
Turritella terebriformis Dall																							
Turritella alticostata Conrad														*				*			*		*
Turritella variabilis Conrad			*			*					*	*		*	*	*		*			*		*
Fossarus lyra Conrad						*	*																
Solarium nuperum Conrad																							
Adeorbis obliquistriabus H. C. Lea							*																
Adeorbis concavus H. C. Lea							*																
Crucibulum auricula var. imbricatum Sowerby																							
Crucibulum grande Say														*				*			*		
Calyptraea centralis Conrad							*																
Crepidula fornicata Say																							
Crepidula aculeata var. costata Morton												*		*	*	*		*			*		*
Crepidula plana Say																							
Polynices duplicatus Say	*		*				*														*	*	*
Polynices heros Say								*	*	*		*		*		*		*			*		*
Calliostoma philanthropus Conrad							*					*											
Calliostoma philanthropus var. basicum Dall							*																
Calliostoma mitchelli Conrad																							
Calliostoma ruffini H. C. Lea							*																
Calliostoma virginicum Conrad																							
Calliostoma harrisii Dall																							
Calliostoma distans Conrad																							
Calliostoma humilis Conrad							*																
Teinostoma nana H. C. Lea							*																
Teinostoma pseudadeorbis Dall																							
Fissuridea catelliformis Rogers							*																
Fissuridea marylandica Conrad																							
Fissuridea redimicula Say																						*	*
Fissuridea alticosta Conrad			*			*								*									
MOLLUSCA. Scaphopoda.																							
Dentalium attenuatum Say						*	*						*	*	*	*		*		*	*	*	*
Cadulus thallus Conrad		*					*	*										*			*		*
MOLLUSCA. Pelecypoda.																							
Nucula proxima Say	*							*	*	*		*											*
Nucula taphria Dall																							*

TABLE SHOWING DISTRIBUTION OF MIOCENE FAUNA.

SPECIES.	Yorktown Formation.											Miscellaneous.				
	York River.				James River.			Nansemond River.								
	Williamsburg—2 mi. north.	Bellefield.	Yorktown.	King's Mill.	Ferguson's Wharf.	Smithfield.	Benn's Church.	Chuckatuck.	Exit.	Reid's Ferry—1½ mi. S. E.	Suffolk.	Westmoreland County.	Stafford County.	Pamunkey River.	James River.	Virginia.
Ilyanassa granifera Conrad			*													
Nassa bidentata Emmons																
Nassa harpuloides Conrad			*													
Anachis harrisii Dall			*													
Murex umbrifer Conrad			*													
Eupleura caudata Say			*								*					
Scalaspira strumosa Conrad			*			*					*					
Urosalpinx trossulus Conrad		*	*			*					*					
Coralliophila lepidota Dall											*					
Scala sayana Dall											*					
Scala lineata Say											*					
Triforis melanura C. B Adams							*									
Seila adamsi H. C. Lea			*								*					
Caecum stevensoni Meyer											*					
Caecum virginianum Meyer			*													
Serpulorbis granifera Say		*									*					
Vermetus sculpturatus H. C. Lea						*		*			*					
Vermetus virginica Conrad											*					
Turritella indenta var. bipartila Conrad																
Turritella terebriformis Dall			*													
Turritella alticostata Conrad		*	*			*					*					
Turritella variabilis Conrad			*			*	*	*	*		*					
Fossarus lyra Conrad											*					
Solarium nuperum Conrad			*													
Adeorbis obliquistriabus H. C. Lea																
Adeorbis concavus H. C. Lea																
Crucibulum auricula var. imbricatum Sowerby			*			*	*	*			*					
Crucibulum grande Say											*					
Calyptraea centralis Conrad																
Crepidula fornicata Say		*	*								*					
Crepidula aculeata var. costata Morton		*	*								*					
Crepidula plana Say		*									*					
Polynices duplicatus Say		*	*			*	*				*					
Polynices heros Say		*							*		*					
Calliostoma philanthropus Conrad		*	*								*					
Calliostoma philanthropus var. basicum Dall			*													
Calliostoma mitchelli Conrad			*													
Calliostoma ruffini H. C. Lea			*													
Calliostoma virginicum Conrad			*								*					
Calliostoma harrisii Dall		*	*													
Calliostoma distans Conrad			*													
Calliostoma humilis Conrad																
Teinostoma nana H. C. Lea																
Teinostoma pseudadeorbis Dall			*													
Fissuridea catelliformis Rogers																
Fissuridea marylandica Conrad			*													
Fissuridea redimicula Say			*			*										
Fissuridea alticosta Conrad		*				*										
MOLLUSCA. Scaphopoda.																
Dentalium attenuatum Say		*	*		*	*	*		*	*	*					
Cadulus thallus Conrad			*			*			*		*					
MOLLUSCA. Pelecypoda.																
Nucula proxima Say			*			*		*	*	*	*					
Nucula taphria Dall						*		*		*	*					

TABLE SHOWING DISTRIBUTION OF MIOCENE FAUNA.

	Calvert Formation.							St. Mary's Formation.															
	Pot. River.	Rap. River.	Mat. River.	James River.			App. River.	Rappahannock River.					Chick. River.	James River.				Blackwater River.		Nottoway River.		Meherrin River.	
Species.	Nomini Cliffs.	Carter's Wharf.	Walkerton.	Richmond.	City Point.	Bailey's Creek.	Petersburg.	Bowler's Wharf.	Farnham—2½ mi. south.	Jones Point—¼ mi. below.	Bayport—2½ mi. below.	Urbanna.	Lanexa.	Claremont Wharf.	Sunken Marsh Creek.	Dillard's Wharf.	Cobham Bay.	Zuni.	South Quay—2 mi. below.	Delaware Park.	Sycamore.	Maddelys Bluff.	Branch's Bridge.
Leda acuta Conrad																							
Yoldia laevis Say														*				*					
Glycymeris americana de France							*																
Glycymeris subovata Say						*	*					*	*	*	*	*		*					
Glycymeris pectinata Gmelin																							
Arca centenaria Say						*	*		*		*	*	*		*	*		*			*		
Arca limula Conrad																							
Arca incile Say						*	*											*			*		
Arca scalaris Conrad							*																
Arca licnosa Say																							
Arca idonea Conrad												*											
Arca staminea Say																							
Arca improcera Conrad																							
Arca elisca Dall	*																						
Melina maxillata Deshayes	*					*		*	*	*	*	*		*	*	*							
Ostrea compressirostra Say			*		*	*		*				*	*	*	*	*		*			*		*
Ostrea sculpturata Conrad			*				*	*					*					*			*	*	*
Pecten jeffersonius Say			*		*	*	*	*				*	*	*	*	*	*	*		*		*	*
Pecten jeffersonius var. edgecombensis Conrad			*			*	*	*				*		*	*	*	*	*			*	*	*
Pecten jeffersonius var. septenarius Say						*	*						*		*	*		*					
Pecten madisonius Say			*		*	*	*				*	*		*	*	*	*				*		
Pecten clintonius Say						*				*			*	*	*		*	*		*	*		*
Pecten virginianus Conrad					*																		
Pecten marylandicus Wagner							*																
Pecten decemnarius Conrad					*																*		
Pecten eboreus Conrad			*		*		*				*		*	*				*			*		*
Plicatula marginata Say							*								*			*				*	
Anomia ruffini Conrad							*																
Anomia simplex d'Orbigny																		*					
Anomia aculeata Gmelin											*	*			*			*					*
Mytilus hamatus Say																							
Modiolus ducatelii Conrad	*						*		*									*	*			*	
Modiolaria virginica Conrad																							
Teredo fistula H. C. Lea						*	*				*	*	*	*					*		*	*	*
Barnea arcuata Conrad																							
Panopea goldfusii Wagner	*					*																	
Panopea reflexa Say	*						*	*		*	*	*		*				*			*		*
Saxicava arctica Linné							*								*			*				*	
Corbula inequalis Say	*		*			*	*	*	*	*	*	*		*	*	*		*			*		*
Corbula cuneata Say																*							
Mya arenaria Linné							*																
Mya producta Conrad																							
Spisula delumbis Conrad																							
Mulinia congesta Conrad	*						*	*	*	*		*	*	*				*	*		*	*	*
Rangia clathrodonta Conrad							*																
Labiosa alta Conrad																							
Ensis directus Conrad							*																*
Ensis ensiformis Conrad														*									
Asaphis centenaria Conrad								*													*		
Tagelus gibbus Spengler								*															
Semele nuculoides Conrad																							
Abra subreflexa Conrad							*																
Cumingia medialis Conrad							*																
Tellina declivis Conrad							*																
Tellina producta Conrad							*																
Macoma conradi Dall																							

TABLE SHOWING DISTRIBUTION OF MIOCENE FAUNA.

SPECIES.	Yorktown Formation. York River. Williamsburg—2 mi. north.	Yorktown Formation. York River. Bellefield.	Yorktown Formation. York River. Yorktown.	Yorktown Formation. York River. King's Mill.	Yorktown Formation. James River. Ferguson's Wharf.	Yorktown Formation. James River. Smithfield.	Yorktown Formation. James River. Benn's Church.	Yorktown Formation. Nansemond River. Chuckatuck.	Yorktown Formation. Nansemond River. Exit.	Yorktown Formation. Nansemond River. Reid's Ferry—1½ mi. S. E.	Yorktown Formation. Nansemond River. Suffolk.	Miscellaneous. Westmoreland County.	Miscellaneous. Stafford County.	Miscellaneous. Pamunkey River.	Miscellaneous. James River.	Miscellaneous. Virginia.
Leda acuta Conrad	...	...	*	...	...	...	...	...	...	...	*	...	...	...	...	...
Yoldia laevis Say	...	*	*	...	*	*	...	*	...	...	*	...	...	...	...	...
Glycymeris americana de France	...	...	*	...	...	*	...	*	...	...	*	...	...	...	...	...
Glycymeris subovata Say	...	*	*	...	...	*	*	...	...	*	*	...	...	...	...	...
Glycymeris pectinata Gmelin	...	...	*	...	...	...	...	...	...	...	*	...	...	...	...	...
Arca centenaria Say	...	*	*	...	*	...	...	...	...	...	...	...	...	...	...	...
Arca limula Conrad	...	...	...	...	...	*	*	*	...	...	*	...	...	...	...	...
Arca incile Say	...	*	*	...	*	*	...	...	*	...	*	...	...	...	...	...
Arca scalaris Conrad	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Arca licnosa Say	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Arca idonea Conrad	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Arca staminea Say	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Arca improcera Conrad	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...
Arca elisca Dall	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Melina maxillata Deshayes	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Ostrea compressirostra Say	...	*	*	...	...	*	*	...	*	...	*	...	...	...	...	...
Ostrea sculpturata Conrad	...	*	*	...	*	*	*	*	...	...	*	...	...	...	...	...
Pecten jeffersonius Say	...	*	*	*	...	*	...	...	*	...	*	...	...	...	...	...
Pecten jeffersonius var. edgecombensis Conrad	...	*	*	...	...	*	*	*	...	...	*	...	...	...	...	...
Pecten jeffersonius var. septenarius Say	...	...	...	...	...	...	...	...	*	...	*	...	...	...	...	...
Pecten madisonius Say	...	*	*	...	...	*	...	...	...	...	*	...	...	...	...	...
Pecten clintonius Say	...	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...
Pecten virginianus Conrad	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Pecten marylandicus Wagner	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Pecten decemnarius Conrad	...	*	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Pecten eboreus Conrad	...	*	*	...	...	*	...	*	*	...	*	...	...	...	...	...
Plicatula marginata Say	...	*	...	...	...	*	*	*	...	*	*	...	...	...	...	...
Anomia ruffini Conrad	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Anomia simplex d'Orbigny	...	...	*	...	...	...	...	...	...	...	*	...	...	...	...	...
Anomia aculeata Gmelin	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Mytilus hamatus Say	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Modiolus ducatelii Conrad	...	...	*	...	...	*	*	*	*	...	*	...	...	...	...	...
Modiolaria virginica Conrad	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Teredo fistula H. C. Lea	...	*	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Barnea arcuata Conrad	...	...	...	...	...	*	...	...	...	...	*	...	...	...	...	...
Panopea goldfusii Wagner	...	...	*	...	...	...	...	...	...	...	*	...	...	...	...	...
Panopea reflexa Say	...	*	*	...	*	*	*	...	*	...	*	...	...	...	...	...
Saxicava arctica Linné	...	...	...	...	...	...	*	*	...	...	*	...	...	...	...	...
Corbula inequalis Say	...	*	...	...	*	*	*	*	*	*	*	...	...	...	...	...
Corbula cuneata Say	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Mya arenaria Linné	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Mya producta Conrad	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Spisula delumbis Conrad	...	...	*	...	...	*	...	...	...	...	*	...	...	...	...	...
Mulinia congesta Conrad	...	...	*	...	*	*	*	*	*	*	*	...	...	...	...	...
Rangia clathrodonta Conrad	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Labiosa alta Conrad	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Ensis directus Conrad	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...
Ensis ensiformis Conrad	...	...	*	...	...	...	...	...	...	...	*	...	...	...	...	...
Asaphis centenaria Conrad	...	...	*	...	...	*	...	...	...	...	*	...	...	...	...	...
Tagelus gibbus Spengler	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Semele nuculoides Conrad	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Abra subreflexa Conrad	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Cumingia medialis Conrad	...	...	*	...	...	*	...	*	...	...	*	...	...	...	...	...
Tellina declivis Conrad	...	...	*	...	...	...	...	...	...	...	*	...	...	...	...	...
Tellina producta Conrad	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...
Macoma conradi Dall	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...

TABLE SHOWING DISTRIBUTION OF MIOCENE FAUNA.

SPECIES.	Calvert Formation.						St. Mary's Formation.																
	Pot. River.	Rap. River.	Mat. River.	James River.			App. River.	Rappahannock River.					Chick. River.	James River.				Blackwater River.		Nottoway River.		Meherrin River.	
	Nomini Cliffs.	Carter's Wharf.	Walkerton.	Richmond.	City Point.	Bailey's Creek.	Petersburg.	Bowler's Wharf.	Farnham—2½ mi. south.	Jones Point—¼ mi. below.	Bayport—2½ mi. below.	Urbanna.	Lanexa.	Claremont Wharf.	Sunken Marsh Creek.	Dillard's Wharf.	Cobham Bay.	Zuni.	South Quay—2 mi. below.	Delaware Park.	Sycamore.	Maddelys Bluff.	Branch's Bridge.
Macoma virginiana Conrad							*																
Petricola harrisii Dall																							
Cooperella carpenteri Dall							*																
Isocardia fraterna Say	*				*	*	*					*		*	*	*		*		*		*	
Cardium virginianum Conrad																					*		*
Cardium laqueatum Conrad							*							*	*								
Cardium robustum Solander																							
Solecardia cossmani Dall							*																
Sportella constricta Conrad							*																
Sportella protexta Conrad							*																
Sportella petropolitana Dall							*																
Sportella compressa H. C. Lea																							
Sportella yorkensis Dall																							
Sportella pelex Dall							*																
Bornia triangula Dall							*																
Montacuta petropolitana Dall							*																
Montacuta sagrinata Dall																							
Aligena aequata Conrad							*																
Diplodonta nucleiformis Wagner							*																
Diplodonta yorkensis Dall																							
Diplodonta acclinis Conrad							*											*					
Diplodonta subvexa Conrad																							
Diplodonta leana Dall							*																
Diplodonta punctulata H. C. Lea							*																
Dosinia acetabulum Conrad	*		*				*			*		*	*			*		*			*		*
Gafrarium metastriatum Conrad																							*
Macrocallista albaria Say			*				*					*											
Callocardia sayana Conrad			*				*	*		*													
Chione latilirata Conrad						*				*	*	*											
Venus plena Conrad																							
Venus tridacnoides Lamarck					*	*	*											*			*	*	*
Venus rileyi Conrad						*	*					*						*				*	
Venus mercenaria Linné												*			*	*							
Codakia speciosa Rogers					*									*									
Phacoides cribrarius Say						*	*							*				*			*	*	
Phacoides anodonta Say	*				*	*	*			*		*		*	*			*		*			
Phacoides contractus Say	*					*						*			*			*			*		*
Phacoides crenulatus Conrad			*			*	*	*		*				*	*			*					*
Divaricella quadrisulcata d'Orbigny					*		*						*	*	*	*				*			
Chama corticosa Conrad						*	*							*	*								
Chama congregata Conrad						*	*					*	*	*	*	*		*			*	*	*
Cardita arata Conrad							*																
Venericardia granulata Say			*		*	*	*			*				*	*	*		*		*	*	*	*
Erycinella ovalis Conrad																							
Crassitellites undulatus Say	*		*			*	*			*	*	*	*	*	*	*		*		*	*	*	*
Crassitellites lunulatus Conrad			*									*						*			*	*	
Astarte symmetrica Conrad					*		*														*	*	
Astarte coheni Conrad							*									*							
Astarte undulata Say	*				*		*				*	*	*	*	*	*	*	*		*	*	*	*
Astarte concentrica var. bella Conrad							*																
Pandora crassidens Conrad																		*			*	*	*
Thracia conradi Couthouy																							*
Thracia transversa H. C. Lea							*																
Margaritaria abrupta Conrad							*											*			*		*
MOLLUSCOIDEA. Brachiopoda.																							
Discinisca lugubris Conrad	*		*		*	*			*		*	*				*							*

TABLE SHOWING DISTRIBUTION OF MIOCENE FAUNA.

	Yorktown Formation.											Miscellaneous.				
	York River.			James River.				Nansemond River.								
SPECIES.	Williamsburg—2 mi. north.	Bellefield.	Yorktown.	King's Mill.	Ferguson's Wharf.	Smithfield.	Benn's Church.	Chuckatuck.	Exit.	Reid's Ferry—1½ mi. S. E.	Suffolk.	Westmoreland County.	Stafford County.	Pamunkey River.	James River.	Virginia.
Macoma virginiana Conrad																
Petricola harrisii Dall		*	*													
Cooperella carpenteri Dall																
Isocardia fraterna Say		*	*													
Cardium virginianum Conrad											*					
Cardium laqueatum Conrad											*					
Cardium robustum Solander			*													
Solecardia cossmani Dall																
Sportella constricta Conrad																
Sportella protexta Conrad																
Sportella petropolitana Dall																
Sportella compressa H. C. Lea			*													
Sportella yorkensis Dall			*													
Sportella pelex Dall																
Bornia triangula Dall			*													
Montacuta petropolitana Dall																
Montacuta sagrinata Dall			*													
Aligena aequata Conrad										*	*					
Diplodonta nucleiformis Wagner			*													
Diplodonta yorkensis Dall			*													
Diplodonta acclinis Conrad			*								*					
Diplodonta subvexa Conrad						*					*					
Diplodonta leana Dall																
Diplodonta punctulata H. C. Lea																
Dosinia acetabulum Conrad		*	*			*			*		*					
Gafrarium metastriatum Conrad			*								*					
Macrocallista albaria Say			*													
Callocardia sayana Conrad		*	*			*		*			*					
Chione latilirata Conrad			*								*					
Venus plena Conrad		*	*													
Venus tridacnoides Lamarck		*	*		*											
Venus rileyi Conrad		*	*		*	*	*				*					
Venus mercenaria Linné																
Codakia speciosa Rogers			*													
Phacoides cribrarius Say			*		*	*										
Phacoides anodonta Say		*	*													
Phacoides contractus Say											*					
Phacoides crenulatus Conrad			*		*		*	*		*	*					
Divaricella quadrisulcata d'Orbigny			*								*					
Chama corticosa Conrad		*	*			*										
Chama congregata Conrad		*	*		*	*	*	*								
Cardita arata Conrad		*	*			*	*	*		*	*					
Venericardia granulata Say		*	*	*			*	*			*					
Erycinella ovalis Conrad			*													
Crassitellites undulatus Say		*	*		*		*	*	*	*	*					
Crassitellites lunulatus Conrad			*			*	*	*		*	*					
Astarte symmetrica Conrad																
Astarte coheni Conrad																
Astarte undulata Say				*	*											
Astarte concentrica var. bella Conrad			*			*	*	*		*	*					
Pandora crassidens Conrad			*			*					*					
Thracia conradi Couthouy			*			*										
Thracia transversa H. C. Lea			*													
Margaritaria abrupta Conrad			*			*					*					
MOLLUSCOIDEA. Brachiopoda.																
Discinisca lugubris Conrad		*	*													

On Calhoun Creek about 1½ miles northwest of Suffolk Waterworks there is an exposure of marl 12 to 14 feet thick containing shells in a sand matrix.

About 1½ miles north of Suffolk the new Tidewater Railroad has made a cut 8 to 12 feet in depth in which there is an excellent exposure of Miocene fossils preserved in a matrix of blue sand. In this vicinity the greatest outcrop of the fossil bed is about 6 feet. It may extend below the level of the cut. Above it there is Pleistocene buff to gray sand with a rather persistent line of coarse cobbles immediately at the base and resting on the shell marl. Many species of fossils have been obtained at this locality.

XIV. *Section at Suffolk Waterworks, about one mile west from Suffolk on Smith Creek.*

			Feet
Pleistocene		Yellow sand carrying considerable gravel......	4-5
Miocene.	Yorktown	Yellow sandy marl with numerous fairly well preserved shells and large quantities of shell fragments	6-8
		Total..............................	13

Below dam of pond which supplies city of Suffolk with water there is an exposure of blue sandy earth containing many well preserved fossils.

Many Yorktown fossils in excellent condition were collected along ditches in edge of Dismal Swamp about 1 mile east of Suffolk from matrix of blue sand about 3 feet below the surface.

PLIOCENE. (?)

The Virginia deposits tentatively referred to the Pliocene belong to the Lafayette formation. They are developed in the extreme western portion of the Coastal Plain near the Piedmont border and consist of gravels and loams which accumulated in shallow marine or estuarine waters in proximity to the shore. Certain marine fossiliferous beds exposed along the Dismal Swamp canals in the extremely southeastern part of the State were formerly thought to represent a marine facies of the Pliocene and have been so described[a] but more recent investigations have shown them to be of later date.

[a]Proc. Acad. Nat. Sci. Phila. for 1898, pp. 414-424, 1899. Norfolk Folio, U. S. Geol. Survey No. 80, p. 3, 1902.

The Lafayette Formation.

Name.—The name Lafayette was proposed by Hilgard[a] in 1891 from Lafayette County, Mississippi, to replace the terms "Orange Sand" hitherto employed in Tennessee and Mississippi and for "Appomattox" which was used in Virginia, District of Columbia, and Maryland, for these deposits.

Since Berry[b] has shown that the so-called Lafayette of the type section in Lafayette County, Miss., is of Eocene age, the question of the proper nomenclature for these surficial deposits of the middle Atlantic slope will have to be reconsidered.

Lithologic character.—The formation is composed of gravels, sands, and loams, usually unconsolidated, although locally cemented by iron oxide. The beds in most cases show approximately horizontal stratification although occasionally stratification lines are not noticeable; at other times the deposits show marked cross-bedding. The materials of the various beds were imperfectly sorted by the waves of the Lafayette sea, so that the gravels, sands, and loam are frequently found intermingled. There is a rough bipartite division in the deposit, as a whole, whereby the gravel occurs in greater abundance at the base and the sand and loam at the top of the formation. In certain places, however, irregular lenses of loam may occur in the lower gravelly portion and beds of gravel and sand in the upper loamy portion.

The gravels of the Lafayette furnish the most characteristic feature of the formation, as they constitute the greater portion of the deposits, and are seen in almost every exposure of the formation. They are of various sizes, ranging from coarse sand to cobbles several inches in diameter generally imbedded in a matrix of sand or sandy loam. Near the crystalline rocks the gravels are commonly coated with a thin layer of ferruginous material which increases their value for road-making purposes. The gravels are almost invariably well-rounded. They are mainly of quartz although pebbles of gabbro and other igneous rocks, usually much decomposed, occur. Pebbles of fine-grained and quartzitic sandstones from the Appalachian region with impressions of Paleozoic fossils are found in places and also pebbles of Newark sandstone. A large part of the gravel is doubtless reworked Potomac material, derived from nearby regions. The heterogeneous character of the pebbles thus furnishes evidence of the varied sources from which the gravels have been obtained.

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[a]Amer. Geol. vol. iii, pp. 129-131.

[b]Jour. of Geol., vol. xix, pp. 249-256, 1911.

Fig. 1.—Locality at Richmond showing Lafayette formation overlying Calvert formation.

Fig. 2.—Pit at Washington, D. C. Showing Lafayette formation overlying Calvert formation.

LAFAYETTE FORMATION OVERLYING CALVERT FORMATION.

Sand forms a rather unimportant part of the Lafayette deposit. Such as is present was doubtless mainly derived from the Potomac beds. Lenses of sand are frequently found in the gravel deposits, but rarely does the sand form beds of any considerable thickness or areal extent. It usually serves as the matrix for the gravels, or else is intimately mixed with the loam.

At points where the formation has suffered little erosion the uppermost beds consist of loam, varying in thickness from a few inches to 10 feet or more. Observations made in many places seem to indicate that this loam is much thicker in the vicinity of Richmond than elsewhere in the State, and there consists of a reddish-brown clayey loam which has been utilized in the manufacture of brick at several points near the city. When wet the loam not infrequently shows a very pronounced mottling of drab and brick-red. Although the loam cap is relatively free from bands of gravels, they are not entirely absent. Single pebbles are not uncommon in the loam, and at times there are well-defined beds of gravel and sand. Some of these pebbles are well rounded but angular quartz fragments are also present, particularly in proximity to the crystalline rocks. There the Lafayette deposits may bear such a striking resemblance to the residual materials of the metamorphic rocks that the presence of occasional rounded water-worn pebbles mixed with the angular fragments is the only clue to the real character of the beds. In such cases the bulk of the material does undoubtedly consist of such residuum which has only been transported a short distance, although, in this process, water-worn gravels which have been transported greater distances have become mixed in small amounts with the residual clay. At the brick yard near the reservoir west of Richmond there is such a clay deposit about 18 feet in thickness, the upper part of which is deep red in color, the lower mottled and white, which could scarcely be distinguished from the residual material, were it not for the presence of a few rounded pebbles distributed through the deposit.

The variable character of the Lafayette materials renders detailed sections of little value, but the following section exposed in northwest Richmond along the Seaboard Air Line Railroad, near Beacon's Quarter Branch, furnishes a good idea of the materials.

Section exposed in Northwest Richmond near Beacon's Quarter Branch.

	Feet
Red clay loam containing many small rounded pebbles irregularly distributed throughout the bed	9
Poorly sorted coarse and fine gravel in matrix of coarse sand, red clay, or arkose (exposed)	18
Total	27

Strike, dip and thickness.—The strike of the Lafayette formation is in a north and south direction, while there is a slight dip to the east, a dip which seems to be due partly to the general slope of the bottom upon which the strata were deposited and partly to a slight subsequent tilting. The thickness is variable, owing largely to the irregularities of the underlying beds, the greatest thickness being in the vicinity of the larger streams of the period which brought down the materials from the westward and deposited them in the Lafayette sea. The waves and currents spread this débris some distance from the stream mouths along the coast thus forming a continuous deposit over the entire submerged area. The coarser materials were mainly dropped in the vicinity of the streams. The thickness generally does not exceed 30 or 35 feet although in some places it is considerably in excess of 50 feet.

Stratigraphic relations.—A very marked unconformity separates the Lafayette from all the underlying formations. In one place or another within the Coastal Plain province it overlies almost every older formation represented within the region, and thin remnants are found in many places, resting on the crystalline rocks of the Piedmont Plateau. In Virginia, the Lafayette is chiefly found in contact with the Potomac, Eocene, and Miocene formations and so far as known is a surface deposit, although locally it, in all probability, dips beneath deposits of Pleistocene age.

Paleontologic character.—Fossils are practically lacking in the Lafayette deposits of the Atlantic Coastal Plain, only a few fragments of molluscan shells which are very imperfect and seem to be re-deposited Miocene fossils have been reported from Virginia deposits of doubtful Lafayette age. Sandstone and chert pebbles containing Paleozoic fossils are found in the formation at many places throughout the district but are of importance only in showing the source of the materials. In regions to the south of Virginia some fossil plants and animals of Lafayette age have been reported, but very little is known concerning them.

Areal distribution.—The Lafayette formation covers the divides along the western part of the Coastal Plain and occurs as outliers resting upon the crystalline rocks of the Piedmont Plateau to the southwest of Washington, west of Richmond, and in many other places. Its distribution is co-extensive with the distribution of the Lafayette terrace described in the chapter on physiography. In its wider distribution the Lafayette formation has been traced as a nearly continuous mantle over the older members of the Coastal Plain deposits all the way from the Mississippi valley, parallel with the Coastal border, to Virginia and southern Maryland, north of which the deposits become less extensive and are represented in northern Maryland, Delaware, and Pennsylvania by only a few small remnants.

Fig. 1.—Excavation at Richmond. Showing Lafayette formation overlying Aquia formation.

Fig. 2.—Surface of country at Malvern Hill. Showing Lafayette surface.

LAFAYETTE FORMATION AND SURFACE.

QUATERNARY.

The Quaternary deposits of the Virginia Coastal Plain belong to the Pleistocene and Recent epochs, both well represented by surface deposits which although thin have a very wide areal distribution. Together they conceal almost all of the older formations except along the valleys where stream cutting has exposed them..

PLEISTOCENE.

COLUMBIA GROUP.

The Pleistocene formations of the Atlantic Coastal Plain are united under the name of Columbia group. The name Columbia was first employed as a formation name, when it was believed that the Pleistocene deposits of the region represented a single stratigraphic unit. Later a two-fold classification of the Pleistocene was recognized and the formations were designated as the Earlier and Later Columbia. Further investigation revealed the fact that the Later Columbia deposits should also be divided. The formations have been given the names of Sunderland, which is the equivalent of the Earlier Columbia, and Wicomico and Talbot which constitute the Later Columbia.

The Columbia deposits consist in general of gravel, sand, and loam. On purely lithologic grounds it is impossible to separate the three formations. In each case the deposits have been derived mainly from the older formations which occur in the immediate vicinity with which is mixed more or less foreign material brought in by streams from the Piedmont Plateau or from the Appalachian region beyond. The deposits of each of these formations are extremely variable and change character according to the underlying formations. Thus materials belonging to the same formation in adjacent regions may differ far more lithologically than the materials of two different formations, lying in proximity to each other. At times the older Pleistocene deposits are somewhat more indurated and the pebbles more decomposed than in the case of the younger formations, but these differences have small value as criteria for the discrimination of the formations, since loose and indurated and fresh decomposed materials occur in each of the formations.

The fossils found in the Pleistocene deposits are far too meager to be of much service in differentiating the formations. It is the exceptional and not the normal development of the formations which has rendered the preservation of fossils possible. They consist principally of plants preserved in fossil bogs, although in a few widely separated places deposits containing great numbers of marine and estuarine molluscs have been found.

Physiographically the Columbia group is readily seen to consist of more than a single unit. Each formation occupies a well-defined wave-built terrace or plain separated by a wave-cut escarpment from the terraces above and below it. At the base of each of the escarpments the underlying Cretaceous and Tertiary formations are at times exposed. The highest terrace is composed of the oldest deposits, the Sunderland, the next lower by the younger, the Wicomico, while the lowest terrace is covered with the youngest or Talbot materials.

In most places where good sections of Pleistocene beds are exposed the materials were evidently deposited continuously from base to summit. In some places, however, certain layers or beds are sharply separated from underlying or overlying beds by uneven lines. These beds usually disappear in short distances and seem to have no relation to similar lines in adjacent regions, showing clearly that they are only local phenomena within the same formation, produced by the contemporaneous erosion of shifting shallow water currents. Since the Pleistocene formations occupy a position so nearly horizontal it should be possible even with the relatively few sections exposed to connect these lines if they represent subaerial erosional unconformities. In the absence of any definite evidence therefore showing these lines to be stratigraphic breaks between two different formations, they have been disregarded. Yet it is not improbable that in some places the waves of the advancing sea may not have entirely removed the beds of the preceding period of deposition over the area covered by its transgression. Especially would deposits laid down in depressions be likely to persist as isolated remnants which later would be covered by the next mantle of Pleistocene materials. If this is the case, each formation from the Lafayette to the Wicomico is probably represented by fragmentary deposits beneath the later Pleistocene formations. Thus in certain sections the lower portions may represent an earlier period of deposition than the upper.

In those regions where older materials are not exposed in the base of the escarpment, each Pleistocene formation near its inner margin probably rests upon the attenuated edges of the next younger formation. Since lithologic differences furnish insufficient criteria for separation of these late deposits and the sections do not afford the data necessary to distinguish between local inter-formational unconformities and widespread stratigraphic unconformities resulting from an erosion interval, the whole mantle of Pleistocene materials occurring at any one level is referred to the same formation. The Sunderland is described as including all the surface

deposits from the base of the Lafayette-Sunderland escarpment to the base of the Sunderland-Wicomico escarpment. The few deposits of Lafayette materials which may possibly underlie the Sunderland are thus disregarded because unrecognizable. Similarly the Wicomico is described as including all the surface deposits extending from the base of the Sunderland-Wicomico escarpment to the base of the Wicomico-Talbot escarpment. In the same way it is possible that remnants of the Lafayette and Sunderland formations may occur beneath the Wicomico. The Talbot is described as including all of the surface deposits extending from the base of the Wicomico-Talbot terrace to the base of the Talbot-Recent escarpment. It may also occasionally conceal beneath its mantle of surface materials some remnants of the earlier Pleistocene formations.

The Sunderland Formation.

Name.—The formation has been so named from its typical development on the peninsula of Calvert County, Maryland, near the little village of Sunderland.

Lithologic character.—The materials which compose the Sunderland formation consist of clay, sand, gravel and ice-borne boulders. These rarely lie in well-defined beds but grade into each other vertically and horizontally. The sands are frequently cross-bedded, while the clays are often developed as lenses. The coarser materials commonly occupy the lower portions of the formation with the finer sand and loam above, but the transition from the coarser to the finer strata is seldom abrupt. Lenses of gravel occur in the upper loam, while beds and lenses of loam are interstratified with the coarse sand and gravel below. The erratic ice-borne boulders are scattered throughout the formation and may occur in the gravel beds near the base of the formation or in the loam above. As in the case of the Lafayette formation, the coarse materials are much more abundant in the vicinity of the larger streams of Sunderland time which transported the gravels from the Piedmond Plateau and the Appalachian region beyond to their present resting place.

That the Potomac River was in existence at that time and emptied its waters into the ocean or a wide estuary in the vicinity of Washington is proved by the coarse sediments that are found in that vicinity. The waves along the shore distributed much of the material brought down by the streams but were not strong enough to transport the coarse material to any great distance from the stream mouths.

Much of the finer materials constituting the Sunderland deposits were undoubtedly derived from the immediately underlying Cretaceous and Tertiary beds, although no inconsiderable amount of both fine and coarse débris unquestionably came from the Lafayette deposits which were largely destroyed over the region of Sunderland deposition by the waves of the advancing sea.

The following section exposed near the Chickahominy River north of Richmond illustrates the character of the Sunderland formation.

Section in Chickahominy River Valley north of Richmond.

			Feet
Pleistocene		Brownish-yellow and mottled clay loam	4
		Band of clay containing few small pebbles	1
		Brown ferruginous sand mixed with clay	5
		Gravel layer with pebbles 1 to 3 inches in diameter	1¼
Miocene.	Calvert	Compact drab clay containing many fossil casts (exposed)	10
		Total	21¼

Strike, dip, and thickness.—The beds of the Sunderland are practically horizontal, the gentle dip to the southeast being very slight and due for the most part to the gentle slope of the Sunderland sea floor in that direction, although a slight tilting since Sunderland time may have increased the southeasterly inclination of the beds. The thickness of the formation is occasionally 40 to 50 feet, but usually considerably less, the thickest portions of the formation representing the filling of depressions in the pre Pleistocene floor.

Stratigraphic relations.—The Sunderland formation throughout the Coastal Plain overlies unconformably the various formations belonging to the Potomac, Eocene, and Miocene groups. It is not improbable that the edges of the Lafayette formation extend out beneath part of the Sunderland deposits although this cannot be determined in the absence of any definite line denoting a stratigraphic break and because of the similarity of the two formations. It is probably overlain unconformably in certain places by the Wicomico and Talbot formations as already explained.

Paleontologic character.—No fossils have been found in the Sunderland deposits of Virginia except the pebbles with Paleozoic remains derived from the Appalachian region. In Maryland some clay beds containing plant remains are found in the deposits but they are neither numerous nor

Fig. 1.—Excavation at Richmond. Showing gravels and loams of the Sunderland formation.

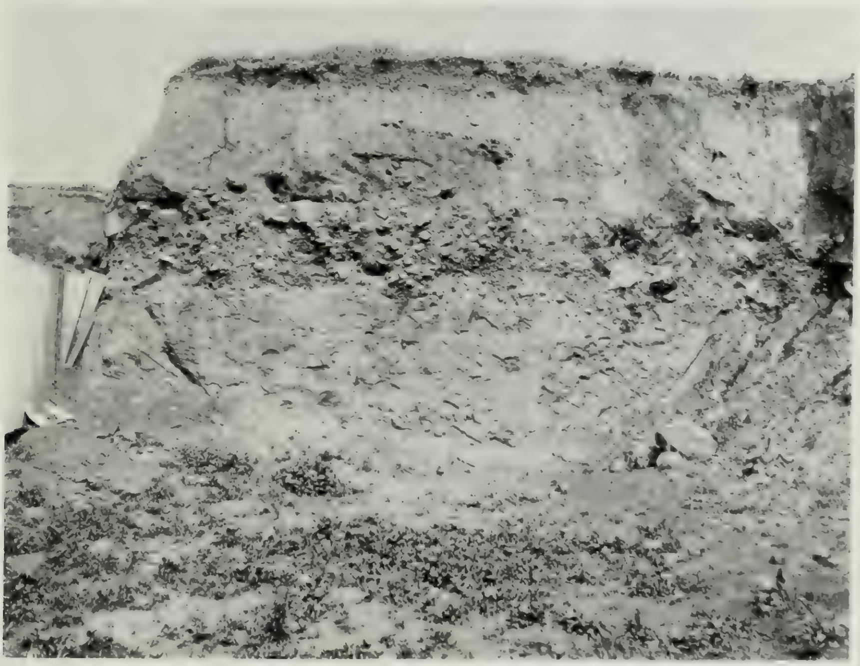


Fig. 2.—Excavation at Washington, D. C. Showing the Wicomico formation overlying crystalline rocks.

SUNDERLAND AND WICOMICO FORMATIONS.

distinctive. A more careful search of the Sunderland deposits of Virginia will undoubtedly show similar plant remains, for plant life must have existed in the region of deposition as shown by the dark color of some of the clays which is evidently due to carbonaceous matter in a finely disseminated condition.

Areal distribution.—The distribution of the formation is co-extensive with that of the Sunderland terrace already described as forming the upland divides between the major streams in a belt extending from Westmoreland to Southhampton counties. The formation except over the broader divides is greatly dissected, and the normal plain-like character of the Sunderland surface is frequently wanting. Since its deposition it has suffered much more erosion, than either of the two younger formations, but enough of the surface still remains to establish its identity over an extensive area.

The Wicomico Formation.

Name.—The Wicomico formation receives its name from the Wicomico River which enters the Potomac from the Maryland side between Charles and St. Mary's counties.

Lithologic character.— The materials which constitute the Wicomico formation are similar to those found in the Sunderland, and in fact, many of them have doubtless been derived from that formation. As stated on a previous page, it would be impossible to distinguish between the Pleistocene formations on the basis of lithologic differences. The criterion of position is the only accurate method of discrimination. The deposits consist of clay, sand, gravel, and ice-borne boulders which grade into each other both vertically and horizontally. It is noticeable, however, as in the case of the Sunderland, that there is a preponderance of the coarser materials at the base of the formation, while the finer materials are largely developed toward the top. Decayed pebbles of the Piedmont crystalline rocks and Paleozoic fossil-bearing pebbles from the Appalachian region are frequently found in the gravel beds or are irregularly distributed in the sands and clays.

In the Potomac valley near Washington, boulders carrying glacial striae have been found in the Wicomico formation. The great size of the boulders and their occurrence with much finer materials furnish the evidence of their transportation by floating ice. The amount of loam present in the Wicomico is exceedingly variable. Wherever the loam cap is well-developed the roads are very firm and the land is suitable for the production of grass and grain, but in those regions where the loam is present in small

quantities, or absent altogether, the roads are apt to be very sandy and the soil poor. Much of the Wicomico loam is suitable for the manufacture of common brick and has been used for such purposes in many places throughout Virginia. The following section of Wicomico materials is exposed in the pit of the West End Brick Company, one-half mile west of Suffolk.

Section exposed in clay pit, one-half mile west of Suffolk.

	Feet
Yellow-clay loam grading downward into a very compact and stiff light-colored drab clay containing numerous iron stains	10
Black clay containing very fine quartz grains	1½
Compact drab clay (exposed)	1
Total	12½

Strike, dip, and thickness.—The Wicomico formation occupies a nearly horizontal position, dipping slightly toward the larger streams and Chesapeake Bay. The inclination of the beds is due primarily to the inclined slope on which the deposits were formed, although the eastward dip has probably been somewhat accentuated by a slight eastward tilting subsequent to the deposition of the strata. The uneven floor upon which the materials were accumulated evidently accounts for the variation in thickness of the formation although deposition was in most cases greater in the vicinity of the stream mouths. The formation is seldom more than 40 feet in thickness and is usually much less.

Stratigraphic relations.—The Wicomico overlies unconformably the various formations of Cretaceous or Tertiary age. It is frequently in contact with the Sunderland on the one hand and with the Talbot on the other and at the Wicomico-Sunderland escarpment it is not improbable that in places the Sunderland extends below this scarp line and may extend out beneath the edge of the Wicomico formation. It is also possible, as above stated, that the Wicomico in certain places extends out beneath the Talbot formation at the base of the Wicomico-Talbot scarp.

Paleontologic character.—The character of the Wicomico deposits is such as to indicate unfavorable conditions for the preservation of fossils. No fossiliferous beds have been reported from Virginia, but in Maryland plant beds within the Wicomico formation have been observed in several different places. Sometimes these plant beds form a layer of impure peat, at other times the plant remains are found as impressions only in beds of drab clay. The plant remains are mainly grasses and stems. Among the plant remains a few wing covers of beetles have also been found.

Fig. 1.—Wicomico-Talbot escarpment at Fredericksburg.

Fig. 2.—Talbot clays at Brick Haven.

WICOMICO-TALBOT ESCARPMENT AND TALBOT CLAYS.

Areal distribution.—The distribution of the Wicomico strata is the same as that of the terrace of the same name described in the chapter on physiography. It occupies the uplands between the lower courses of the large estuaries and frequently extends up the larger valleys as a narrow or wide discontinuous terrace to the head of tide-water. Along the peninsulas between the James and Potomac rivers the Wicomico forms a band of variable width occupying a position between the Sunderland covered divides and the Talbot terrace that skirts the rivers and Chesapeake Bay. South of the James River, however, the Wicomico occupies a wide area extending from the James River to the North Carolina line and beyond, and from the western margin of the Dismal Swamp to the vicinity of the Blackwater River. In this broad area the Sunderland is absent and the Wicomico formation covers the stream divides which are broad and flat, while the streams have cut shallow valleys below the general level of the surrounding country. An escarpment separates the formation from the Sunderland formation above and another divides it from the lower-lying Talbot formation. The escarpment between the Wicomico and Talbot is very well marked in many places, being especially well-developed along the western margin of the Dismal Swamp and from there continues almost due north to the James River. It is also plainly shown between the James and York rivers between Newport News and Yorktown, and north of Gloucester Point on the peninsula between the York and Rappahannock rivers. The Wicomico surface is very conspicuous along the upper estuarine portion of the Rappahannock River where it is frequently over a mile in width and forms a pronounced terrace below the Sunderland deposits that cover the divides.

The Talbot Formation.

Name.—The Talbot formation has received its name from Talbot County, Maryland, where the deposits of this age form a broad terrace bordering the numerous estuaries.

Lithologic character.—The materials which compose the Talbot formation consist of clay loam, peat, sand, gravel, and ice-borne boulders. As in the Sunderland and Wicomico formations, these materials grade into each other both vertically and horizontally and the same bipartite division with the coarser materials beneath and the finer ones above is present in the Talbot as in the others. There is on the whole much less decayed material in the Talbot than in the two preceding formations and this gives to the formation a much younger appearance although this difference cannot be

always relied on. The Talbot also contains less coarse material than do the other two Pleistocene formations. Sand and loam predominate, although some gravel and boulders occur either in bands or irregularly distributed through the finer materials in almost every region where the formation is developed. The Potomac River evidently brought down a great many glacial boulders during the Talbot submergence, and these carried by floating ice were dropped in the various deposits then forming. A number of these have been found in the region of Washington which show their glacial character by the planation they have suffered and the glacial striae they bear. Some of them may have come from the earlier Pleistocene deposits, and have been re-deposited, but it is improbable that many have had such an origin.

The materials of the Talbot were derived in part from the destruction of the older Pleistocene strata and the underlying Cretaceous and Tertiary formations by the waves of the Talbot sea and its estuaries, yet, as in the preceding periods, the streams doubtless brought down much additional material from the Piedmont Plateau and the Appalachian region beyond. The Talbot materials therefore like those of the preceding formations are exceedingly heterogeneous in character.

A type of deposit not thus far recognized in the older Pleistocene formations in Virginia, although occurring in them elsewhere, is peat which is developed extensively along the Rappahannock River. About a mile above Tappahannock the river has cut into an old Talbot swamp deposit containing peat and many upright cypress stumps which are still in an excellent state of preservation.

Section exposed in Rappahannock River bluff, one mile above Tappahannock.

	Feet
Yellowish-brown loam grading downward into sand	12
White to ash-colored fine sand	4
Band of fine gravel with a few pebbles an inch in diameter	3½
Drab clay containing pieces of lignite and plant impressions with many cypress knees and stumps derived from the bed below	0-4
Compact brown to black peat containing numerous upright cypress knees and stumps in place, some of the stumps reaching 4 feet in height and 5 feet in diameter (exposed)	1-4½
Total	28

The river in cutting into the deposit has removed in places the clay and peat, leaving many knees and stumps exposed. The line of separation

Fig. 1.—Low bluff ½ mile below Bayport Wharf, Rappahannock River. Showing cypress stumps and knees in peat bed of the Talbot formation.

Fig. 2.—Low bluff 1½ miles above Tappahannock, Rappahannock River. Showing cypress stumps and knees in peat bed of the Talbot formation.

CYPRESS STUMPS AND KNEES IN PEAT BED OF TALBOT FORMATION.

between the drab clay and the gravel band above is a very sharp one and represents a decided change in deposition. It is believed that the swamp accumulation was formed in the lower course of a tributary stream of the Rappahannock which had been dammed by the formation of a bar across its mouth. Many examples of such ponded streams are now to be observed all along the tidal estuaries. Partially separated from the waters of the Rappahannock, swamp vegetation, probably similar to that now growing in the Dismal Swamp, flourished until an extensive bed of vegetable débris was formed. A further submergence of the area, however, depressed the protecting sand-bar, permitting the Rappahannock River waters to flood the area, finally killing the swamp vegetation. During this greater submergence the upper three beds of the described section were probably deposited.

Along the Dismal Swamp canal between Deep Creek and Lilly, N. C., and also along the feeder which connects Lake Drummond and the canal, strata containing marine fossil shells are exposed. The dredge has brought up quantities of these shells in several different places. As stated on a previous page these fossils were formerly believed to belong to the Pliocene but are now regarded as of Talbot age. The matrix is a bluish-green argillaceous sand and shells are in excellent state of preservation.

The following section passed through in sinking a well just to the east of Norfolk is typical of the normal development of the Talbot formation.

Well Section near Norfolk.

			Feet
Pleistocene.	Talbot	Fine white quartz sand	18
		Blue clay	13
		Sandy clay	$3\frac{1}{2}$
		Loose sand	8
		Gravel with water-bearing horizon immediately overlying shell marl	$7\frac{1}{2}$
		Total	50

Strike, dip, and thickness.—The Talbot strata, as in the case of the Wicomico and Sunderland formations, occupy a practically horizontal position with but a slight inclination toward the main waterways of the Atlantic Ocean, the Chesapeake Bay and the tributary estuaries.

The average thickness of the formation over the greater portion of the Virginia Coastal Plain is somewhat less than 30 feet. It thickens to the eastward, however, and in the vicinity of Norfork and Portsmouth seems to be as much as 50 to 60 feet in thickness. In Accomac County on the Eastern Shore the Talbot attains its greatest thickness and as shown by

somewhat generalized well records seems to be considerably more than 100 feet thick. Part of this thickness may represent the seaward portions of the earlier Pleistocene formations that were not destroyed before the Talbot was deposited. This variability in thickness is in part also explained by the uneven surface upon which the formation was deposited. The proximity of certain regions to mouths of streams during the Talbot submergence also accounts for the increased thickness of the formation in these areas.

Stratigraphic relations.—The Talbot rests unconformably in different portions of the region upon various older formations of Cretaceous-Tertiary age. It doubtless occasionally rests upon some remnants of the Lafayette, Sunderland, or Wicomico formations, although as yet no positive evidence has been found to indicate such relations to the older Pleistocene formations. In all the subaerial portion of the Coastal Plain the Talbot formation where present forms the surface material except where covered by Recent deposits of sand (sand dunes) or humus. In the submarine portion the Talbot apparently dips beneath the Recent terrace now in process of formation.

Paleontologic character.—The fossils thus far reported from the Talbot deposits in Virginia consist chiefly of marine shells from the eastern portion of the Dismal Swamp and of plant remains found in swamp deposits at many points.

Miss J. A. Gardner has determined the following molluscan forms collected from the Talbot deposits of the Dismal Swamp canal between mileposts 15 to 16.

Nucula proxima Say.
Arca transversa Say.
Arca ponderosa Say.
Abra aequalis Say.
Divaricella quadrisulcata d'Orb.
Venericardia tridentata Say.
Ostrea virginica Gmelin.
Venus mercenaria (Linné).
Tellina tenera Say.
Cumingea tellinoides (Conrad).
Ensis directus (Conrad).
Mulinia lateralis Say.
Corbula contracta Say.
Marginella limatula Conrad.
Polynices duplicatus (Say).
Crepidula plana Say.
Crepidula fornicata (Linné)
Urosalpinx cinereus (Say).
Eupleura caudata (Say).
Columbella lunata (Say).
Ilyanassa obsoleta (Say).
Nassa trivittata (Say.)
Fulgur canaliculatum (Linné).
Fulgur carica Gmelin.
Terebra dislocata (Say).
Tornatina canaliculata (Say).

In addition to the preceding species *Rangia cuneata* (Gray) has been found at Pope Creek and Newport News and *Unio* sp. on the Rappahannock River, 1½ miles below Port Royal.

Mr. E. W. Berry had also determined the following plant remains:

Taxodium distichum (Linné) Rich.	Bald Cypress
Tappahannock (seeds, cone-scales and stumps)	
Rappahannock, ½ mi. below Bayport wharf (stumps)	
Rappahannock, just above Parrotts Creek (stumps)	
Atlantic Coast, just south of Virginia Beach (stumps)	
Fagus americana Sweet	Beech
Tappahannock (nuts)	
Nomini Cliffs (leaves and burrs)	
Betula nigra Linné	Birch
Rappahannock, 1½ mi. below Port Royal (leaves)	
Hicoria glabra (Mill.) Britt.	Hickory
Tappahannock (nuts)	
Quercus sp.	Oak
Rappahannock, 1½ mi. below Port Royal (leaves)	
Nomini Cliffs (acorns)	
Celtis occidentalis Linné	Hackberry
Tappahannock (fruits)	
Vitis sp.	Grape
Tappahannock (seeds)	
Ilex Cassine Linné	Dahoon Holly
Rappahannock, 1½ mi. below Port Royal (leaves)	
Nyssa biflora Walt.	Gum
Tappahannock (seeds)	
Dendrium pleistocenium Berry	Sand Myrtle
Rappahannock, 1½ mi. below Port Royal (leaves)	

Areal distribution.—This formation has an extensive development in the Coastal Plain region of Virginia, covering all of the Eastern Shore counties of the State and the greater portion of the counties bordering Chesapeake Bay on the west and south. In addition to this wide bordering plain it is developed along all of the tide-water estuaries and often extends inland almost to the head of tide. It forms the lowest subaerial terrace of the region although wanting in many places where by recent cutting the streams have removed it forming cliffs that expose the older formations. Alexandria, Newport News, and Norfolk are all built on the Talbot plain and the formation is seen in its typical development in the vicinity of these cities.

RECENT.

The Recent deposits embrace chiefly those which are being laid down today over the submarine portion of the Coastal Plain and along the various estuaries and streams. To these must also be added such terrestrial deposits as talus, wind-blown sand, humus, and deposits forming in the swamps and bogs. In short, all deposits which are being formed today under water or on the land by natural agencies belong to this division of geological time.

The Recent terrace now under construction along the present ocean shoreline and in the bays and estuaries is the most significant of these deposits

and is the last of the terrace formations which began with the Lafayette, the remnants of which today occupy the highest levels of the Coastal Plain, and which has been followed in turn by the Sunderland, Wicomico, and Talbot.

Beaches, bars, spits, deltas, flood-plains, and other formations composed of gravel, sand, clay, and peat are being built up on this terrace belt and are constantly changing their form and position with the variations in currents and winds. Along the streams flood-plains are formed that in the varying heights of the water suffer changes more or less marked. On the land the higher slopes are often covered with débris produced by the action of frost and the heavy downpours of rain which form, in certain places, accumulations of large proportions known as talus and alluvial fans.

A deposit of almost universal distribution in this climate is humus or vegetable mold, which, being mixed with the loosened surface of the underlying rocks, forms our agricultural soils. The ultimate relationship therefore of the soils to the underlying geological formations is evident.

The deposit of wind-blown sands more or less apparent everywhere, as may be readily demonstrated at every period of high winds, is especially marked along the sea coast, particularly in the vicinity of Cape Henry where sand dunes of large dimensions have been formed. The accumulation of vegetable débris in bodies of water lying in undrained regions and in ponded creeks is also considerable in many places. This is well shown in the comparatively thick deposits of partially decayed vegetation in the Dismal Swamp. Other accumulations in water and on the land are going on all the time and with those already described represent the formations of Recent time.

Fig. 1.—View showing large cypress trees in Lake Drummond, Dismal Swamp.

Fig. 2.—Cypress trees and knees of Dismal Swamp.

CYPRESS TREES AND KNEES IN DISMAL SWAMP

CORRELATION OF THE VIRGINIA COASTAL PLAIN FORMATIONS

The geological formations of the Virginia Coastal Plain are closely related to those found in the adjacent states of Maryland and North Carolina and there is not a single formation in the State that cannot be traced into adjoining states and in some instances even over a wider area. Most of the formations are fossiliferous, some of them containing a great profusion of the remains either of animal or plant organisms. It is possible, therefore, in most instances to correlate the formations by the use of paleontological criteria. The Patuxent, Patapsco, Aquia, Nanjemoy, Calvert, St. Mary's, and Yorktown formations can all be correlated on this basis, while the later Lafayette and Columbia formations can only be satisfactorily correlated on the basis of physical criteria since the animal and plant remains found in the Talbot formation, although clearly of post-Tertiary age, are yet inadequate to separate the Talbot from the other Pleistocene formations.

CRETACEOUS.

The formations of Cretaceous age found in Virginia can be correlated with Cretaceous deposits elsewhere on the evidence of both lithology and paleontology. The Lower Cretaceous formations, which alone appear at the surface, afford much more satisfactory evidence for detailed correlation than do the Upper Cretaceous which have been observed only in deep-well borings far to the east of the other Cretaceous outcrops. Dr. L. W. Stephenson and Mr. E. W. Berry, under the direction of Dr. T. Wayland Vaughan, have greatly enlarged our knowledge of the stratigraphy and paleontology of the South Atlantic and Gulf States, and the results of their work have been available for the comparisons with the southern districts south of North Carolina.

Lower Cretaceous.

The Lower Cretaceous formations of Virginia which have been already described under the name of the Potomac Group comprise part of the belt of Lower Cretaceous deposits which have been found over a wide area along the eastern border of the continent.

The Patuxent Formation.

The Patuxent formation is similar both in lithologic character and in fossil content to the Patuxent formation of Maryland where the deposits were first described under this name. The materials comprising the Patuxent in both areas are in a marked degree arkosic and predominantly arenaceous with layers and lenses of clay from which the plant fossils have been largely derived. The arenaceous beds are universally cross-bedded with many pebble bands and coarse beds of gravel. Overlying the Patuxent formation in Maryland is a deposit of clay, often lignitic, called the Arundel formation, that was evidently formed in the post-Patuxent valleys soon after the close of the Patuxent epoch since the flora shows few if any changes from that of the preceding Patuxent. The Arundel formation has furnished many Dinosaurian remains. The Patuxent formation includes the James River and part of the Rappahannock series as well as portions of the Aquia series earlier described by Ward.

When a comparison is instituted between the Patuxent formation of Virginia and the Patuxent and Arundel formations of Maryland the following characteristic plant fossils may be recognized as common to the two areas:

Arthrotaxopsis grandis Fontaine
Brachyphyllum parceramosum Fontaine
Cephalotaxopsis magnifolia Fontaine
Dioonites buchianus (Ett.) Born.
Nageiopsis longifolia Fontaine
Nageiopsis zamioides Fontaine
Frenelopsis parceramosa Fontaine
Equisetum Lyelli Mantell
Equisetum Burchardti (Dunk.) Brongn.
Rogersia longifolia Fontaine
Cladophlebis virginiensis Fontaine
Cladophlebis ungeri (Dunk). Ward
Ctenopteris insignis Fontaine
Nilsonia desinerve (Font.) Berry.
Podozamites distantinervis Fontaine

The Patuxent formation is represented in North Carolina by deposits which are evidently physically continuous with the Virginia strata although the formation in southern Virginia and northern North Carolina is covered at the surface by the transgression of the later Tertiary and Quaternary sediments just as it is in narrower areas in Virginia and in Maryland. The materials comprising the formation in North Carolina are similar in character but thus far no fossil remains have been found by which paleontological comparisons can be made. The senior author of this report in discussing the Lower Cretaceous formations of the Atlantic border region says:[a]

"Deposits of Lower Cretaceous age are most extensively developed in Maryland and northern Virginia, where the Patuxent (arkosic sands, gravel,

[a]Clark, W. B. Bull. Geol. Soc. Amer., Vol. xx, p. 647 (1908), 1910.

clays), Arundel (clays, lignites, carbonate of iron concretions), and Patapsco (variegated clays, sands) formations occur. The organic remains consist for the most part of dinosaurs and plants. Lull, who has recently studied the former, and Berry, who has been engaged in an investigation of the latter, are agreed that they are of Lower Cretaceous age, so that the earlier questionable reference of the Patuxent and Arundel formations to the Jurassic is now abandoned. Farther southward in North Carolina is the Cape Fear formation (arkosic sands, clays), so called by Stephenson, which is evidently continuous with the Patuxent formation, although the basal beds of the Coastal plain are transgressed by later formations in southern Virginia and northern North Carolina. No fossils have been found in the Cape Fear formation, but the strata are similar lithologically to the Patuxent farther north and unlike the Arundel and Patapsco."

The name "Cape Fear" formation, proposed for the North Carolina deposits, is now regarded as a synonym of Patuxent. The formation has also been recognized in the "Hamburg beds" of South Carolina.

The senior author of this report in discussing the correlation of the Atlantic Coast Lower Cretaceous formations with those of the Gulf says:[a]

"A correlation of the Cretaceous deposits of the Atlantic coast with those of the eastern Gulf cannot be in all instances satisfactorily made, since the Gulf Cretaceous series has never been worked out in detail, and much yet remains to be done in the determination of the range of the species. Strata hitherto called Tuscaloosa are found at the base of the Cretaceous series, in eastern Alabama as well as in Georgia, which must be regarded as identical with the Patuxent-Cape Fear formations of the Atlantic border. There is a marked unconformity at the top of the beds, and deposits supposed to represent the Eutaw, or possibly in part the Tuscaloosa farther west, are found above. Little is known regarding the western extension of these lower beds, although it is possible that they may be found beneath the surface in central Alabama, and perhaps farther westward. These older beds are, so far as known, unfossiliferous, but are now regarded as belonging unquestionably to the Lower Cretaceous."

There is little doubt therefore but that the Patuxent formation is a physicially continuous deposit from northern Delaware through Maryland, Virginia, North Carolina, South Carolina, and Georgia to eastern Alabama. Determinable fossils have only been found in the northern part of the district but further investigation may show their presence in other areas as well as in Maryland and Virginia. Among deposits containing a similar flora

[a]Ibid. pp. 651, 652.

may be mentioned the Trinity beds of Texas, the Lakota formation of the Black Hills of Dakota and Wyoming, the Kootenai formation of British Columbia and Montana, part of the Shasta group of the Pacific coast, and the Kome beds of Greenland. It is also probable that the Morrison beds of the Rocky Mountain district belong here.

There has been a prolonged discussion as to the age of these beds since Professor Marsh considered the Dinosauria found in the overlying Arundel formation in Maryland to possess Jurassic affinities. The paleobotanists, on the other hand, have consistently maintained the Lower Cretaceous age of the deposits, basing their conclusions on the extensive flora which is closely similar to that found in the Neocomian beds of Portugal, Mexico, and Japan and in the Wealden deposits of England and Germany, now generally regarded as of Lower Cretaceous age. More recent studies of the Dinosauria have led Professor Lull to regard them also as of Lower Cretaceous age and the Patuxent formation is therefore referred to that horizon in this report.

The Patapsco Formation.

The Patapsco formation in Virginia is similar lithologically to the formation thus named in Maryland while the flora of the two areas is practically identical. The deposits in both regions consist of highly colored and variegated clays which grade over into highly colored arenaceous clays, while coarser sandy beds are at times interstratified.

The Patapsco formation includes the Mt. Vernon and part of the Aquia series of Ward; also part of Fontaine's Rappahannock series.

Among the more important plant fossils found common to the two areas are:

Acrostichopteris longipennis Fontaine
Araucarites aquiensis Fontaine
Araliaephyllum magnifolium Fontaine
Araliaephyllum crassinerve (Fontaine) Berry
Celastrophyllum parvifolium (Fontaine) Berry
Celastrophyllum acutidens Fontaine
Nelumbites tenuinervis (Fontaine) Berry
Nelumbites virginiensis (Fontaine) Berry
Populophyllum minutum Ward
Pinus vernonensis Ward
Sapindopsis brevifolia Fontaine
Sapindopsis magnifolia Fontaine
Sapindopsis variabilis Fontaine
Sassafras parvifolium Fontaine
Widdringtonites ramosus (Fontaine) Berry
Hederaephyllum dentatum (Fontaine) Berry
Podozamites lanceolatus (L. & H.) Schimper

The Patapsco deposits are not known on the Atlantic seaboard to the south of the James River area but extend northward across Maryland and Delaware into Pennsylvania, their most northern occurrence being isolated outcrops in certain of the deeper valleys to the west of Philadelphia.

The Patapsco formation is in all probability to be correlated with the Fuson formation of the Black Hills while it represents a part of the marine Lower Cretaceous of the western Gulf and Pacific coast regions.

The flora according to European standards has a marked Albian facies, presenting many points in common with the Albian of Portugal described by Saporta, several species as well as many genera being identical.

Upper Cretaceous.

The Upper Cretaceous deposits of Virginia have been observed only in deep-well borings near the eastern border of the Coastal Plain, the Lower Cretaceous being directly overlain unconformably along the line of outcrop by the overlapping Tertiary formations. The senior author of this report in discussing the Upper Cretaceous of the Atlantic border region says:[a]

"Upper Cretaceous deposits extend from New Jersey, where they are most extensively developed, northeastward along the New England coast and southward through Delaware and Maryland to the Potomac valley. Strata of this age have been penetrated in well borings in eastern Virginia, but do not appear along the line of outcrop, being overlapped by Tertiary formations. In North Carolina Upper Cretaceous deposits again appear, and cover a wide area to the south of the Hatteras axis.

"The Raritan formation (clay, sands, gravels) of the northern part of the Coastal plain evidently represents the earliest phase of Upper Cretaceous deposition, these beds overlying the Lower Cretaceous strata, where exposed, with a marked unconformity. Beds of similar age do not occur in North Carolina.

"The overlying Magothy-Matawan formations (sands, clays, lignitic and glauconitic beds), which outcrop throughout the area from the Potomac basin northward to the islands off the New England coast, are represented in North Carolina by the Black Creek formation (sands, clays, lignitic and glauconitic beds), the same fauna and flora characterizing the deposits in both areas. The minor subdivisions established in New Jersey, where these formations are best developed can not be recognized elsewhere, and the changes in physical conditions bringing about the differentiation of faunules there described were evidently only local.

"The Monmouth formation (glauconitic beds, sands, clays) characterized by the introduction of *Belemnitella americana* and other forms can be traced through New Jersey, Delaware, and Maryland, and again reappears in North

[a] Op. cit. pp. 647 648.

Carolina, the deposits here and in South Carolina having been named the Peedee formation (glauconitic beds, sands, clay). The reappearance of one of the earlier faunules toward the close of the Monmouth, as observed in New Jersey, is wanting.

"The Rancocas and Manasquan formations (glauconitic and calcareous beds) of the northern part of the Coastal plain are chiefly found in New Jersey and Delaware, and contain a younger fauna. Such late Cretaceous strata are not known elsewhere along the Atlantic border."

The Virginia deposits belong to the Magothy-Matawan-Monmouth series of formations but the exact position of the beds cannot be satisfactorily determined although they probably belong to the lower rather than to the upper portion of this series, the character of the materials suggesting the Matawan formation. More paleontological evidence is required to finally determine this point.

The senior author of this report in discussing the correlation of the deposits with those of the Gulf and other areas says:[a]

"Reference has already been made to the fact that the Magothy-Matawan-Monmouth formations of the northern part of the Coastal Plain are to be correlated with the Black Creek-Peedee formations of North Carolina. It seems equally certain that these find their counterpart in the Tuscaloosa-Eutaw- Ripley of the eastern Gulf, with the exception of such portion hitherto referred to the Tuscaloosa as is known to be of Lower Cretaceous age.

"Very little is known of the fauna of the earliest marine sediments commonly referred to the Eutaw, although the few fossils found come from apparently interstratified marine beds not unlike those in the Black Creek and the Magothy. It is also apparent that the fauna of certain strata of the lower portions of what has been regarded as Ripley, on the Chattahoochie River, represents the Black Creek and the Magothy-Matawan, but whether these beds should be considered Ripley or as representing part of an earlier horizon, and thus included in the Eutaw, can only be determined by further investigations.

"It is largely a question, in any event, as to whether the term Ripley or Ripleyan shall be used in a broad way to include the beds containing both the lower and upper faunas, in which case even the Eutaw would have to be regarded as Lower Ripley, or whether two formations are to be recognized to be called Ripley and something else, either Eutaw or Tombigbee, as certain stratigraphic and paleontologic facts suggest. Continuous sedimentation, with gradual change in the character of the materials until the beds became

[a] Op. cit. pp. 652-654.

wholly or at least largely marine, doubtless continued during the life of these faunas here, as in the other areas, and such facts as are available point to this conclusion. Such being the case, the term Ripleyan might perhaps with greater propriety be applied, as has been frequently done to the entire fauna, if it seemed inadvisable to restrict it, in which event a new formational name would have to be employed for the upper beds. It is evident that the greater part of the deposits comprising the Tuscaloosa must of necessity be associated with the Upper Cretaceous strata of the Gulf region, and a group term to include this entire series of deposits would not be inappropriate. A final decision on these points, as well as a satisfactory correlation of the Middle Atlantic with the Eastern Gulf deposits must be deferred, however, until more is known of the stratigraphy and paleontology of the latter region.

"When a comparison of the Atlantic Coast Cretaceous fauna is made with that of the European Cretaceous we find that its general character is that of the Senonian, and the view has been commonly held by invertebrate paleontologists that all of the marine beds of the Atlantic and Eastern Gulf coasts represent that epoch of the Cretaceous, with the possible exception of certain later deposits in New Jersey which have been regarded by the writer and others as of Danian age. Some even include in the Senonian all of the Upper Cretaceous strata, both marine and non-marine, from New Jersey to the Mississippi basin, since even the lowest known Upper Cretaceous deposits in this area (Raritan formation) contain a few marine invertebrates of possibly identical species with those of higher horizons. Those who hold this view necessarily consider that the earlier Turonian and Cenomanian epochs are unrepresented, since every one now agrees that the unconformably underlying deposits are Lower Cretaceous. It is quite possible, however, that a more exhaustive study of these faunas may show them to be in part of pre-Senonian age.

"It is essential, however, before passing final judgment on the basis of marine invertebrates to examine the evidence furnished by the fossil plants which occur in great variety in the lowest beds beneath those containing the marine invertebrates, as well as in interbedded strata in the middle of the series. Berry, who has been engaged in a comparative study of the Cretaceous floras of the Atlantic and Gulf coasts, states that the Magothy-Black Creek flora is identical with that of the Tuscaloosa-Eutaw. Not only do they have the same floral characteristics, but the species are in a larger number of instances identical. Furthermore, the same forms occur in the Woodbine formation in Texas and in the Dakota beds of the West. The flora has been

regarded as characteristically Cenomanian, although it may represent the somewhat meager Turonian flora which succeeds it, and therefore belong to that horizon. On the other hand, it is distinctly older than the Montana flora of the West and its Senonian equivalent in Europe.

"The evidence afforded, therefore, by the invertebrates and plants is apparently in conflict, since the former present a Senonian facies throughout, according to many invertebrate paleontologists, while the latter are regarded by paleobotanists to be characteristically Cenomanian, or possibly Turonian, in age. In this connection we find in the western Gulf that the Woodbine formation, which is the representative of the Dakota sandstone farther west, and which contains, as already pointed out, a Black Creek-Magothy-Tuscaloosa flora, is succeeded by marine beds known as the Eagle Ford and Austin Chalk formations which represent the Colorado group farther west, and that these are again succeeded by deposits containing the Ripley fauna, the latter being regarded as the equivalent of the Montana group of the Rocky Mountain district. Since the Dakota has been generally regarded as containing a Cenománian flora and the Montana a Senonian fauna and flora, the Colorado and its equivalents have been assigned to the Turonian. As the Montana flora is considered by paleobotanists as quite distinct from and much younger in its facies than the Dakota, it is difficult to see, if we are not to ignore the evidence of paleobotany, how, as some have supposed, the entire series of Upper Cretaceous sediments on the Atlantic and Eastern Gulf coasts can be assigned to the Senonian. Such a conclusion is still further weakened by the fact that the Woodbine beds may be stratigraphically continuous beneath the Mississippi embayment with the Tuscaloosa deposits farther east in which the same flora occurs. A much more exhaustive study of the stratigraphy of the Cretaceous deposits of the Central and Western Gulf regions is clearly demanded, therefore, before these questions can be finally settled.

"It is apparent, in any event, that we are still forced to consider the possibility of the Upper Cretaceous sediments of the Atlantic and Eastern Gulf coasts representing horizons earlier than the Senonian. Since the Turonian has not been recognized by either a distinct fauna or flora in the series of conformable strata under consideration, it is quite possible that a Cenomanian flora, once established, continued its existence in America later than the close of the Cenomanian epoch in Europe. At the same time it is conceivable that the earlier elements of the invertebrate fauna are somewhat older than paleozoölogists have recognized, and that a greater or less portion of the series under discussion must therefore be regarded as Turonian. The

evidence of the plants is certainly favorable to this interpretation, as the European Turonian flora, although a very sparse one, presents some marked points of agreement with portions of the flora under consideration."

Table of Cretaceous Formations.

	Long Island and southern New England	New Jersey	Delaware and Maryland	Virginia	North Carolina	Alabama
Upper Cretaceous		Manasquan				
		Rancocas	Rancocas			
		Monmouth	Monmouth		Peedee	Ripley Selma
	Matawan	Matawan	Matawan		Black Creek	Eutaw
	Magothy	Magothy	Magothy			Tuscaloosa
	Raritan	Raritan	Raritan			?
Lower Cretaceous			Patapsco	Patapsco		?
			Arundel			Lower Cretaceous
			Patuxent	Patuxent	Patuxent	?

TERTIARY.

The Tertiary deposits of Virginia represent both the Eocene and the Miocene and also doubtfully the Pliocene in the Lafayette formation. All of the Eocene and Miocene formations are very fossiliferous so that comparisons can be made with well-known faunas elsewhere while the correlation of the Lafayette formation is based entirely on physical grounds.

Eocene.

The Virginia Eocene formations already described under the name of Pamunkey group are limited to the province comprising Virginia, Maryland, and Delaware and already described by the senior author of this report.[a]

The same author in discussing the district from New Jersey to North Carolina in a recent paper says:[b]

"The Eocene deposits of New Jersey, known as the Shark River formation (glauconitic beds), apparently overlie the Manasquan formation conformably. The contained fossils show the beds to be of early Eocene age. Farther south in Maryland and Virginia, but nowhere in contact with the Shark River beds, is a series of younger and conformable Eocene deposits known as the Aquia and Nanjemoy formations (glauconitic beds, clays, sands), which overlie the Cretaceous unconformably. Entirely discontinuous are the North Carolina Eocene strata, which Miller has named the Trent and Castle Hayne formations (calcareous marls, clays), and which are of still later Eocene age. The latter are apparently unconformable to each other, and likewise rest unconformably on Cretaceous deposits."

The Aquia Formation.

The Aquia formation can be traced from southern Virginia across Maryland to the Delaware border. The materials throughout this area are similar and the fossils identical. Both to the north and to the south of this region the Aquia formation is transgressed by later deposits and does not again appear at the surface. Among the characteristic fossils are:

Pleurotoma potomacensis Clark and Martin
Turritella mortoni Conrad
Panopea elongata Conrad
Meretrix ovata var. *pyga* Conrad
Dosiniopsis lenticularis (Rogers)
Venericardia planicosta var. *regia* Conrad
Crassatellites alaeformis (Conrad)
Pholodomya marylandica Conrad
Modiolus alabamensis Aldrich
Ostrea compressirostra Say
Cucullaea gigantea Conrad

The Aquia formation affords many species identical with those of the Wilcox of the Gulf, the fossils on the whole being more characteristic of the lower division although a number of forms are found only in the upper Wilcox and Claiborne horizons in Alabama. It is evident that many of the

[a] Clark, W. B. Bull. U. S. Geol. Survey, No. 141, 1896; Clark and Martin, Md. Geol. Survey, Eocene, 1901.

[b] Clark, W. B. Bull. Geol. Soc. Amer., Vol. xx, p. 649 (1908), 1910.

species common to the two areas differ widely in their geological range. This is evidently due in part to the difference in physical conditions in the Gulf and middle Atlantic regions and in part, in all probability, to migration. It is apparent, however, that the fauna of the Aquia formation is more closely related to the Wilcox than to earlier or later horizons and that there is a somewhat closer resemblance to the lower than to the upper Wilcox.

The correlation of the Aquia formation with European deposits is even less definite. Dall correlates[a] the entire middle Atlantic coast Eocene with the Suessonian of Europe. It is doubtful, however, whether the Nanjemoy formation should be thus correlated since the writers believe that the Eocene deposits of Virginia and Maryland represent more than the Wilcox of the Gulf and therefore must be regarded as having a wider range in the European Eocene.

The Nanjemoy Formation.

The Nanjemoy formation has been recognized in Virginia and in southern Maryland, the materials and fossils being characteristic of the deposits throughout this area. Among the typical forms found in the two states are:

Corbula aldrichi Meyer
Meretrix ovata var. *ovata* (Rogers)
Meretrix subimpressa Conrad
Lucina dartoni Clark
Venericardia potapacoensis Clark and Martin
Ostrea sellaeformis Conrad
Leda improcera (Conrad)
Leda potomacensis Clark and Martin
Nucula potomacensis Clark and Martin

The Nanjemoy formation affords species that are characteristic of the upper Wilcox and the lower Claiborne although the relationships are on the whole closer with the former than with the later. It is possible that both may be represented.

The correlation of the Nanjemoy formation with the European Eocene cannot be satisfactorily made. It is possible that it represents a somewhat higher horizon than the Suessonian and may represent the Londonian and even in part the Parisian. The difficulty in correlating the middle Atlantic Coast Eocene deposits with those of Europe is due to the fact that the few identical species in the two areas have a wide geological range and are thus of little value for purposes of detailed comparison. Other common species may ultimately be found but more exhaustive collections than have been made will be necessary. Until such investigations are completed the correlation of the deposits on the two sides of the Atlantic can be at best only provisional.

[a]18th Ann. Rept. U. S. Geol. Survey, part 2, pp. 327-348, 1898.

The Trent and Castle Hayne formations are younger than the Virginia Eocene formations and evidently represent the Jackson and possibly in part the upper Claiborne as well. A more exhaustive study of the fossils is necessary before an exact correlation can be made.

Table of Eocene Formations.

New Jersey	Delaware and Maryland	Virginia	North Carolina	Alabama
			Castle Hayne	Jackson
			Trent	Claiborne
	Nanjemoy	Nanjemoy		Wilcox
	Aquia	Aquia		
Shark River				Midway

MIOCENE.

The Miocene formations of Virginia are in part continued into Maryland[a] and Delaware on the north and in part into North Carolina on the south. The senior author in discussing the formations in this district says.[b]

"The Miocene deposits are best developed in the Chesapeake Bay region, where four formations have been recognized, known as the Calvert (clays, sandy clays, diatomaceous earth, shell marls), the Choptank (sandy clays, sands, shell marls), the St. Mary's (sandy clays, sands, shell marls), and the Yorktown (fragmental shell marls, sandy clays, sands). The Choptank does not occur in Virginia, and the Yorktown is absent in Maryland. These formations are evidently continued in part into New Jersey, as similar faunas have been found there, but the relationships have not been fully worked out as yet. To the southward the St. Mary's and Yorktown formations, transgressing the earlier deposits, continue on into North Carolina, both being found over extensive areas to the north of the Hatteras axis, where the Yorktown overlies the St. Mary's unconformably. To the south of the Hatteras axis deposits very similar to the Yorktown formation, both lithologically and paleontologically, but known under the name of the Duplin formation, are found resting unconformably on pre-Miocene formations."

[a] Clark, Shuttuck, and Dall. Md. Geol. Survey, Miocene, 1904.
[b] Clark, W. B. Bull. Geol. Soc. Amer., Vol. xx, p. 649, 1908.

The Calvert Formation.

The Calvert formation is practically continuous with deposits thus named in Maryland and Delaware. Both the materials and the fossils are similar in the two areas although some forms are found in Maryland which do not occur in Virginia and the same is true regarding a number of Virginia species. Deposits containing similar forms are found in southern New Jersey where they have been described under the name of Kirkwood formation.

The Calvert deposits are not known in North Carolina, the St. Mary's formation transgressing the Calvert before the southern limits of Virginia are reached. All of the Miocene deposits in North Carolina so far as known belong to much more recent horizons. Dr. T. W. Vaughan[a] has identified Sloan's Marks Head marl at Porter's Landing, Savannah River, Georgia, as the approximate equivalent of the Calvert which would indicate the presence of deposits of this age in the south Atlantic district.

The correlation of the Atlantic coast Miocene with the Miocene deposits of Europe has not been attempted in detail and there are many points of difference that make such correlation difficult. Dall states that in a general way, allowing for local peculiarities, the Miocene of north Germany compares well and agrees closely with that of Virginia. Berry who has determined the plant remains from the Calvert formation of Virginia regards them as equivalent to the middle Miocene of central Europe.

The St. Mary's Formation.

The St. Mary's formation contains the same materials and faunas over a wide area to the north of the Hatteras axis and has been traced almost continuously from North Carolina across Virginia and Maryland into Delaware while St. Mary's forms have also been found in the deep wells of eastern New Jersey. The absence of the Choptank formation in Virginia brings the St. Mary's fauna into sharper contract with the underlying Miocene than in Maryland. The faunas are not identical in all particulars in the two areas, some species found only at lower horizons in Maryland continuing on into the St. Mary's in Virginia.

The St. Mary's formation does not appear as far as known, to the south of the Hatteras axis in North Carolina but Dr. T. W. Vaughan considers the Edisto beds of South Carolina as probably of the same age.

[a]Science, N. S., Vol. 31, pp. 833, 834, 1910.

The Yorktown Formation.

The Yorktown formation can be traced from southern Virginia southward into North Carolina, the same materials and fauna persisting, but it is unknown in northern Virginia and Maryland. To the south of the Hatteras axis the Duplin formation is closely related to the Yorktown deposits. Dr. Dall[a] in discussing this relationship says:

"A study of these (fossils from the Natural Well) indicated their general parallelism with the upper or Yorktown Miocene of Virginia, with which their deposition may have been partially synchronous. The fossil species, are, however, largely distinct from those of the Yorktown beds and of a more tropical aspect. It is probably that in Miocene times, as at the present day, there was a difference in the marine faunas of the two regions, that at Yorktown and Suffolk being more allied to the subjacent temperate fauna of the older Miocene of Maryland and Virginia, while that in North Carolina contained more southern types. Yet even this seems hardly sufficient to account for more than part of the difference. It is probable that with the elevation of the Gulf and Florida coasts, which closed the deposition of the cold-water Miocene on those shores, the changes in ocean currents which made the water warmer and invited the return of the subtropical fauna, banished at the end of the Oak Grove epoch, extended at least as far as North Carolina. To this change I ascribe part of the new aspect of the Duplin fauna, which would thus be due to the combination of two factors."

As already stated a correlation of the Atlantic coast with European Miocene deposits cannot be readily made although according to Dall "the Miocene fauna of Northern Germany compares well and agrees closely with that of Maryland (and Virginia), while the Mediterranean Miocene finds a closer analogue in the more tropical fauna of the Duplin beds of the Carolinas."

Table of Miocene Formations.

Maryland	Virginia	North Carolina
	Yorktown	Yorktown and Duplin
St. Mary's	St. Mary's	St. Mary's
Choptank		
Calvert	Calvert	

[a] Wagner Free Institute of Science, Trans., Vol. ii, pt. 6, pp. 1598-1603.

Pliocene (?).

The Lafayette Formation.

The Lafayette formation is similar both in its materials and physiographic relations to deposits which have received the same name throughout the Atlantic and Gulf borders. The formation occupies a relatively narrow belt along the western margin of the Coastal Plain and at times occurs in isolated areas on the Piedmont Plateau. It forms the oldest and highest of the series of the late Tertiary and Quaternary terraces that characterize the Coastal Plain. In the absence of fossils this physiographic feature becomes one of the most important criteria for the correlation of the formation. The structure and composition of the strata already described are also highly characteristic and aid materially in the recognition of this formation whereever found.

The age of the Lafayette formation is in much doubt. From its known stratigraphic relations it is evidently younger than the latest Miocene beds and probably younger than the marine Pliocene of the Atlantic border. These earlier beds were apparently subjected to a long period of erosion before the deposition of the Lafayette began. Again, after the close of the Lafayette it is probable that an extensive epoch of erosion occurred before the Columbia deposits of Pleistocene age were laid down. This would assign to the Lafayette formation a position between the marine beds of Pliocene age and the oldest deposits of recognizable Pleistocene age. The Lafayette formation is therefore either of late Pliocene or early Pleistocene age. The consensus of opinion hitherto has been in favor of the former interpretation but in the absence of fossils it is practially impossible to reach a positive conclusion. It is evident that more adequate evidence must be secured before the question can be regarded as settled, especially, as Berry has shown, as has previously been mentioned, that the type sections in Lafayette County, Miss., are of Eocene age, thus necessitating a new name for the later Atlantic coast deposits.

QUATERNARY.

The Quaternary formations of Virginia comprise both Pleistocene and Recent deposits. Since they represent the most recent phase of deposition and still preserve in a marked degree their original form, physiographic criteria are of much importance in interpreting and correlating the deposits.

Pleistocene.

The Pleistocene formations already described under the name of the Columbia Group have been recognized over a wide area along the Atlantic seaboard south of the terminal moraine of the last glacial period. The distribution and origin of these deposits along the continent border have been discussed by Dr. G. B. Shattuck.[a]

The senior author of this report has recently discussed the correlation of the Pleistocene formations in the Middle Atlantic Coast area. He says:[b]

"The Pleistocene deposits consist chiefly of a series of terraces, the earliest found along the western border of the Coastal Plain, encircling the margin of the Piedmont plateau and the higher elevations of the Coastal Plain, and extending up the estuaries and streams, where it finally merges into fluviatile deposits. This oldest terrace, known as the Sunderland formation, can be traced from the glacial deposits southward across Maryland and Virginia into North Carolina. The Sunderland terrace, which has an elevation of 150 to 200 feet along its shoreward margin, declines gradually seaward and toward the larger valleys, where it reaches to below 100 feet in height. Another terrace is found in central and southern North Carolina between the Lafayette and Sunderland and has been named the Coharia formation by Stephenson.

"The next younger terrace, known as the Wicomico, encircles the preceding terrace at a lower elevation, and forms a well marked belt along the eastward margin of the latter although extending up the river channels in some places to the Piedmont border, where it also merges into fluviatile deposits. Its landward margin has an elevation of 80 to 110 feet, from which point it declines seaward and toward the larger stream valleys to 50 to 60 feet in elevation. Its surface is not as extensively dissected as the Sunderland terrace, and near its inner margin are found many buried valleys that were cut at the close of Sunderland time.

"Below the Wicomico terrace, and encircling it, is the third or youngest terrace of the Pleistocene, which has been called the Talbot. The landward margin of the Talbot terrace is from 40 to 60 feet in height, from which elevation it gradually declines seaward until it reaches nearly, if not quite, to sea-level. The Talbot terrace has been but slightly dissected, compared with the earlier terraces, and forms the coastal lowlands. It may also be traced as a low terrace far up the estuaries and river valleys until it also

[a]Amer. Geol., Vol. xxviii, pp. 87-107, 1901; Md. Geol. Survey, Pliocene and Pleistocene, pp. 291, 1906.

[b]Clark, W. B. Bull. Geol. Soc. Amer., pp. 650, 651 (1908), 1910.

merges into true fluviatile deposits. In North Carolina it divides into two terraces, constituting the Chowan and Pamlico formations.

"All of these Pleistocene formations have been traced step by step throughout the area in question, and present the same general characters everywhere."

The Sunderland Formation.

The Sunderland formation, like the Lafayette formation, can only be correlated on the basis of physical criteria. The more or less dissected terrace surface has been traced from Delaware southward across Maryland and Virginia into North Carolina.

The materials comprising the Sunderland formation are similar to those found to the northward although some changes occur due to differences in the character of the rocks from which the sediments were derived. Its position enwrapping the higher portion of the Coastal Plain beneath the Lafayette formation is closely similar to the Sunderland of more northern districts. This oldest of the Pleistocene terraces is everywhere more highly dissected than the later terraces at lower levels while the materials as a whole are somewhat more extensively disintegrated, although this factor must be employed with care since similarly decayed materials are often to be found in later deposits.

The Sunderland formation corresponds approximately with the Earlier Columbia of McGee and Darton and with parts of the Bridgeton and Pensauken as described by Salisbury in New Jersey.

The age of the Sunderland and later terraces has been generally recognized as Pleistocene. The fossil leaves of the Sunderland belong mostly to living species while the relatively small physical changes that have occurred indicate that the deposits cannot be older than Pleistocene. Furthermore its probable contemporaneity with pronounced glacial conditions is evidenced by the striated boulders sometimes found in the deposits. Whether they represent the earliest phase of Pleistocene deposition has not been settled and cannot be until the age of the Lafayette formation is finally determined.

The Wicomico Formation.

The Wicomico formation is devoid of fossils of correlative value. Its equivalency with the deposits similarly named in Maryland is shown by its terraced surface occupying a position at approximately the same level and beneath the Sunderland terrace already described. It enwraps the earlier

terrace often with a pronounced escarpment throughout the central and northern Coastal Plain and has been traced continuously from the valley of the Deleware River across Delaware, Maryland, and Virginia into North Carolina. The surface of the Wicomico terrace is less dissected than that of the Sunderland and in general the materials are less decayed.

The few plant fossils found in. the Wicomico formation belong essentially to living species although in a few instances they seem to be ancestral types that have since become differentiated into those living in the sand barrens and in the upland country. The differences, however, are so slight that there is no question but that the flora as a whole must be referred to the Pleistocene. The presence of ice-borne boulders furnishes evidence for its probable contemporaneity with the ice-invasion although the particular drift sheet with which the formation should be correlated has not yet been determined.

The Wicomico represents the upper portion of the Later Columbia formation of McGee and Darton and a part of the Pensauken formation of Salisbury.

The Talbot Formation.

The Talbot terrace as already described is found at a lower level than the Wicomico and enwraps the same extending up the valleys until it merges into the fluviatile deposits of the Coastal Plain streams as in the case of the preceding Pleistocene terraces. It can be traced all the way from the Delaware valley across Delaware, Maryland, and Virginia to the North Carolina line.

The Pleistocene age of the formation is proved by the molluscan fossils found along the Dismal Swamp canal and at Cornfield Harbor on the Potomac River, most of which belong to species still living in the adjacent sea. Its Pleistocene age is further shown by its evident contemporaneity with a part of the ice-invasion of the northern part of the country, as evidenced by the numerous ice-borne boulders found in its deposits. The formation represents the lower part of the Later Columbia described by McGee and Darton and corresponds to the Cape May and part of the Pensauken formations of Salisbury.

In North Carolina two mappable terrace deposits have been found below the Wicomico level. To these, the names, Pamlico and Chowan, have been applied. Together they seem to be the equivalent of the Talbot and the explanation seems to be found in a halting during the uplift following the deposition of the main portion of the Talbot which permitted the ocean waves to cut a cliff that still persists over extensive areas south of the

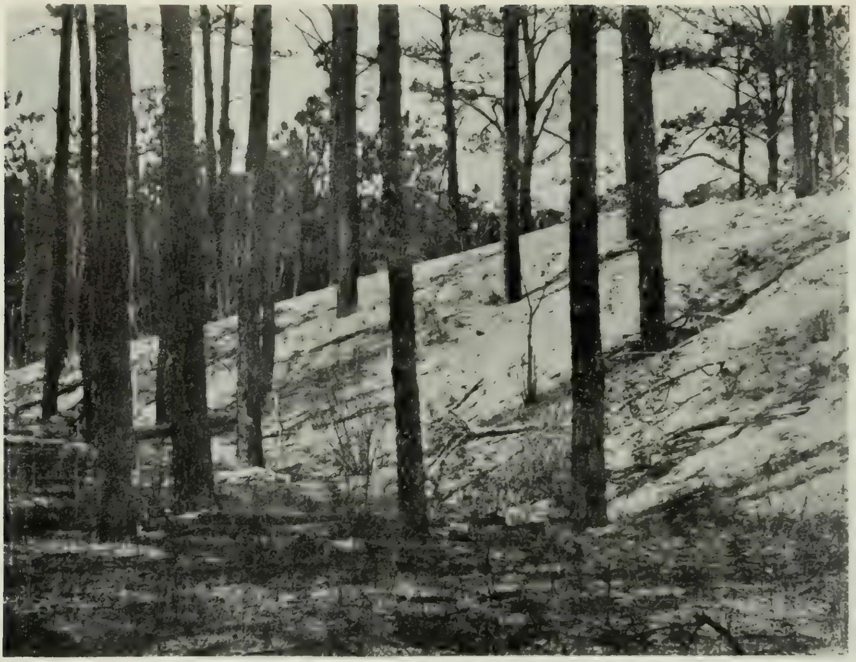


Fig. 1.—View of sand dunes, Cape Henry.

Fig. 2.—View of sand dunes, Cape Henry.

SAND DUNES, CAPE HENRY.

Fig. 1.—View of sand dunes, Cape Henry.

Fig. 2.—View of sand dunes, Cape Henry.

SAND DUNES, CAPE HENRY.

Virginia line. Indications of such a division of the Talbot can be observed in a few places in Virginia but are not distinct enough to be mapped. Unlike conditions in the two adjoining regions give evidence of the differential movements that took place during the uplifts and submergences of the Pleistocene.

Table of Pleistocene Formations.

	Delaware and Maryland	Virginia	North Carolina
Columbia	Talbot	Talbot	Pamlico Chowan
	Wicomico	Wicomico	Wicomico
	Sunderland	Sunderland	Sunderland
			Coharie

Recent.

The recent deposits consist of beaches, sand bars, sand spits, sand dunes, flood plains and other fluviatile deposits, and humus. These deposits represent the results of all the geological agencies now at work in modifying the surface of the Coastal plain, and are variously developed in the different portions of the region, dependent on the character of the adjacent formations and the distribution of the various streams and currents. A great Recent terrace, similar in all particulars to those of Pleistocene date, is now being laid down beneath the bed of the present sea and estuaries and along the border of the coast and tidal streams. Beaches are frequently being formed, while great sand bars are common. Sand dunes adjoin the coast, and are especially prominent in southern Virginia and North Carolina, where from Cape Henry southward they are a conspicuous feature of the coastal topography. The rivers during flood are constructing flood plains, which coalesce with the deposits of the estuaries. Over the land surface the transfer of material and the development of soils, with their accompanying humus, are going on everywhere.

GEOLOGICAL HISTORY OF THE VIRGINIA COASTAL PLAIN

The formations which occur within the Virginia Coastal Plain are in every case continued either to the north or to the south and the geologic history which is here outlined has been based on work done not only in the Virginia area but also throughout the entire region of the North Atlantic Coastal Plain from New England to the Carolinas.

A study of the geologic history of the region shows that it has been a long and complicated one. This is evidenced by the many different kinds of strata represented and by the relations which they bear to one another. There are deposits that were plainly formed in fresh or brackish water, while others show evidence of deposition in marine waters; some have been deposited in water of shallow depth, others in deeper water; while breaks in the continuity of the different strata indicate that the region has been subjected to many elevations and subsidences from the time of the formation of its earliest rocks down to the present day.

Pre-Cretaceous history.—The oldest Coastal Plain deposits are of Lower Cretaceous age. They can be found everywhere resting upon crystalline rocks of probably pre-Cambrian and early Paleozoic age. These form the floor upon which the Coastal Plain deposits have been laid down, a floor which near the present shore-line lies about 2,000 feet beneath the sea level, but which rises to the west and finally appears at the surface to form the Piedmont Plateau, the physiographic province which forms the western boundary of the Coastal Plain.

In the Piedmont it is exceedingly difficult to interpret the past history for the reason that the whole area has been subjected to many great changes which have essentially modified original materials, yet the studies that have been carried on have revealed many facts concerning the original conditions of the rocks now composing it. Many of these were originally sedimentary deposits, but in the processes of metamorphism have now lost nearly all traces of their original character. Furthermore these old sedimentaries have been broken through in many different places by igneous materials which have also been greatly altered. Thus the Piedmont metamorphics contain representatives of both igneous and sedimentary rocks. Time and again they have been subjected to the various processes of metamorphism by which the original mineral composition has been greatly changed, and the beds have been folded and crumpled.

During the latter portion of the Paleozoic era the Piedmont floor of the Coastal Plain and also the present Piedmont Plateau seem to have formed a land surface which probably extended far to the east of the present shore-line. How much farther we do not know, but perhaps to the edge of the present continental shelf. The streams draining this land-mass carried great quantities of terrigenous materials to the west where they were deposited in the Paleozoic sea. These strata now form the Blue Ridge and Allegany Plateau of the western portion of the State. During part of the Triassic period a shallow estuary was formed near the eastern margin of the present Piedmont Plateau, into which some of the streams carried their load of sediment, and along the margin of which marsh plants grew in such abundance that their remains now form the coal beds in the vicinity of Richmond.

It is of course possible that other changes occurred during the Paleozoic and early Mesozoic periods which have left no record. The region may have been depressed beneath the ocean waters and covered with sediments many times, but if such is the case, later erosion has removed them from that portion of the crystalline surface accessible to our study. Whether sediments of later Paleozoic and early Mesozoic age overlie the older crystallines to the east of the present coast line cannot be with absolute certainty determined but it is within the range of possibility.

Early Cretaceous history.—The recorded history of the Virginia Coastal Plain begins with early Cretaceous time. The earliest of the known unconsolidated deposits lying upon the floor of crystalline rocks belong to the Patuxent formation of the Potomac Group. These deposits indicate a submergence of the entire Coastal Plain to perhaps a short distance beyond the "fall line." The water covering the region was shallow and seems to have been estuarine in character. The cross-bedded sands and gravel furnish evidence of the shifting currents as do also the rapid changes in the character of the materials both horizontally and vertically. The presence of numerous land plants in the laminated clays shows the proximity of the land. Since the Patuxent deposits are so very extensive it is somewhat difficult to explain the physical conditions then prevailing. It has been suggested that possibly there was a land barrier somewhere to the east, probably beyond the present Atlantic shore-line, which kept out the ocean waters. The presence of large quantities of lignitic material seems to point to the existence of marshes in many places. Continuous deposition did not prevail over the submerged area during the entire time; erosion by means of which some of the earlier Patuxent deposits were destroyed is

shown in a number of instances. The occurrence of clay balls of Patuxent age within the Patuxent sand beds along the James River has already been noted. During the Patuxent submergence the region was probably beneath the water for some distance to the west of where we find the most westerly deposits now, but these deposits must have been very thin and they have since been removed by erosion.

The deposition of the Patuxent formation was ended by an uplift which brought the region above the water and inaugurated an erosion period which persisted long enough to permit the removal of a vast amount of material. This was followed by a subsidence in which many of the stream valleys but lately eroded were occupied for a portion of their courses by bogs and swamps. In these marshes there was an extensive development of plant life, and in them also were deposited the iron ores which in Maryland have been so extensively worked since Colonial days. These deposits constitute the Arundel formation.

After another elevation and erosion interval the land was again depressed beneath estuarine waters. Deposits similar to those which had formed during the Patuxent submergence were laid down throughout the northern Atlantic Coastal Plain. In Maryland these are very well exposed but in Virginia they appear at the surface chiefly along the Potomac River. They constitute the Patapsco formation. The greater abundance of red clay found in the Patapsco indicates that the source of some of the streams was in a region where the decomposition of the igneous rocks and the oxidation of the residual material had been going on for a long time. A marked change in the flora as compared with that of Patuxent and Arundel time indicates that a considerable period probably elapsed before the deposition of the Patapsco formation.

Following the deposition of the Patapsco formation the region again became land through an upward movement which drained all of the previously existing estuaries and marshes. Erosion at once became active and the Patapsco surface was dissected.

Late Cretaceous history.—A very long period of erosion apparently elapsed before the deposition of the Upper Cretaceous formations in Virginia. The land barrier that had kept out the ocean waters during the Potomac epoch had been broken down. The streams from the low-lying land evidently carried to the ocean at this time only small amounts of fine sand and mud which afforded conditions favorable to the production of glauconite and permitted the accumulation of the greensand beds which are so characteristic of the Upper Cretaceous formations along the Atlantic

Fig. 1.—General view of Turner's clay pit, Ettricks, near Petersburg.

Fig. 2.—View of sandstone blocks in old quarry at Coles Landing, Aquia Creek.

CLAY PIT AND SANDSTONE BLOCKS.

coast. The shore-line during the Upper Cretaceous evidently lay farther to the east in Virginia than it had during the Potomac period. As has been stated before, the Upper Cretaceous deposits do not outcrop in Virginia but have been penetrated by the deep-well borings at Fairport and in the vicinity of Norfolk.

Eocene history.—In early Tertiary time a depression carried most of the region again beneath the waters of the ocean and the Eocene deposits were formed. The great amount of glauconite present in these formations indicates that the adjacent landmass must have been low and flat so that the streams carried only small amounts of terrigenous materials. The water in which these were deposited was doubtless not deep, as glauconite is not known to be produced at great depths. The land-derived material at the beginning of the Eocene consisted of coarse sand and occasionally small, well-rounded pebbles. Later the material brought in by the streams was much finer and consisted of fine sand or clay. Many forms of animal life characteristic of the infralittoral zone existed in these waters and their remains are now found composing layers of marl frequently many feet in thickness.

Studies of the fossils found in the Eocene deposits indicate that there were many changes in the fauna during this time. These changes were probably influenced to a greater or less extent by variations in the physical environment, yet the character of the deposits themselves gives little evidence of such changes. Instead, it seems probable that the conditions under which the Eocene deposits were produced were remarkably uniform, considering the great length of time which elapsed from the beginning to the close of the period.

Miocene history.—Eocene sedimentation was brought to a close by an uplift in which the shore-line was carried far to the eastward, and probably all of the present State of Virginia became land. This was followed by submergence, and another cycle was begun. The deposits of the Calvert were now laid down upon the eroded land surface of the Nanjemoy. Sluggish streams carried in fine sand and mud which they gave to the waves and ocean currents to spread over the sea bottom. The shore-line in the northern part of the Coastal Plain of Virginia was not quite as far west as it had been during the Eocene submergence. In the central and southern portions, however, it was farther west than it had been at any previous time since the beginning of Coastal Plain deposition. Thus we find in northern Virginia the Calvert beds resting upon the Nanjemoy, in the James River basin upon the Aquia, while somewhat farther to the south they are found in im-

mediate contact with the crystalline rocks of the Piedmont. Near the shore leaves from land plants carried out to sea by the streams were dropped and their remains have been preserved in the fine-grained deposits of the Calvert in the vicinity of Richmond.

Near the beginning of the Miocene submergence certain portions of the sea bottom received little or no material from the land, and the water in those places was well suited as a habitat for diatoms. These must have lived in the waters in countless millions, and as they died their silicious shells fell to the bottom and produced the diatomaceous or infusorial earth beds which are so common in the lower part of the Calvert formation. Many protozoa as well as higher forms of animal life, particularly mollusca, lived in the same waters, and their remains are found plentifully distributed throughout the beds. At certain times conditions must have been especially favorable for animal life, as may be inferred from the great shell marl deposits which are found in so many places throughout Virginia.

After the deposition of the Calvert formation the region was again raised and subjected to erosion for a short period, and on sinking once more beneath the sea, the Choptank formation, which has been differentiated north of the Potomac River, was laid down contemporaneously with the advancing ocean. The Choptank formation lies unconformably on the Calvert in Maryland and farther north transgresses it and rests upon the Cretaceous deposits. During this last submergence conditions changed somewhat so that materials of different lithologic character were brought in. The sands of the Choptank in turn gave place to clay deposits alternating with layers of sand. These latter constitute the St. Mary's formation which in Virginia unconformably overlies the Calvert formation. These changes in physical conditions of sedimentation were accompanied by slight changes in the climate, which reacted upon the life forms inhabiting the ocean waters. Consequently we find in the St. Mary's formation a somewhat different assemblage of fossil forms. In general these are closely related to forms which now exist in somewhat higher latitudes. They indicate a slightly colder climate than had existed during the formation of the Choptank strata.

After the deposition of the St. Mary's an uplift brought practically the entire Coastal Plain of the State above the water, and a short period of erosion was inaugurated. The Yorktown period of submergence followed. During this period the ocean shore-line extended across the eastern part of the Coastal Plain, the Eastern Shore of Chesapeake Bay and the counties bordering Chesapeake Bay along the Western Shore were alone submerged. Molluscan life was very abundant during this time, and along the low, sandy

beaches great accumulations of fragmental shell deposits were formed. These constitute the shell beds so well exposed in the cliffs at Yorktown. All during the Miocene there had been a gradual change in marine life, and in this latest period the forms were more closely related to the present fauna than those that lived earlier.

Pliocene history.—During the earlier Tertiary periods the adjacent land of the Piedmont Plateau had been subjected to erosion. The low character of the country prevented the weathered products of the Piedmont from being carried off by the sluggish streams. In late Pliocene time a subsidence occurred which brought the entire Coastal Plain and the margin of the Piedmont Plateau beneath the water. This was the greatest submergence that had occurred since the close of the Lower Cretaceous and perhaps was even more extensive than that during the Patuxent epoch. Coincident with the subsidence there seems to have been a slight elevation and tilting of the region west of the shore-line. The heads of the streams were given renewed force, enabling them to carry down and deposit over this region large quantities of gravel and sand derived from the Piedmont and Appalachian rocks to the westward. The evidence for the source of this material is found in the many different pebbles which, by their lithological character or the fossils which they contain, can be traced to their origin. In the vicinity of Washington and Richmond gravels are found containing fossils of Devonian and Carboniferous age, brought from beyond the Blue Ridge. These show that the Potomac and James rivers had extended their drainage basins far to the west. During the submergence of the region beneath the Lafayette sea conditions were not uniform over the entire area, as we have gravel deposits forming in some places at the same time that other beds were being deposited in adjoining regions, yet on the whole, sedimentation was remarkably uniform over the entire area, considering the circumstances under which it took place. Over the former land surface a persistent cap of gravel was deposited. Toward the close of Lafayette submergence the land slowly rose, and the velocity of the streams was so changed that gravel could no longer be carried down except in occasional freshets. Fine sand and loams were laid down over the gravel which had been previously deposited. This loam, which is so extensively developed over a large part of the region occupied by the Lafayette deposits, apparently marks the end of Pliocene sedimentation. It marks also the last time that the entire Coastal Plain of Virginia has been beneath the ocean waters.

Pleistocene history.—At the close of the Pliocene epoch the region was raised again and extensively eroded. It appears that after the close of the

post-Lafayette erosion the Coastal Plain was gradually lowered beneath the waves and the Sunderland sea advanced over the sinking region. The Sunderland submergence was not as great in extent as the Lafayette submergence and a portion of the Coastal Plain remained above water. The waves of the Sunderland sea cut a scarp line against the existing headlands of the Lafayette and older rocks. These scarp lines are prominent in some places and obscure in others, for the reason that sea cliffs were not always cut as the ocean was bordered in some places by sandy beaches, while in other places the low cliffs cut in the unconsolidated sediments have now been entirely worn away. The waves supplied the materials, the undertow and shore current swept it out and deposited it; the basal member of the Sunderland formation, a mixture of clay, sands and gravel, representing the work of currents along the advancing margin of the Sunderland sea. The upper member of clay and loam was deposited on the other hand in deeper water after the shore-line had advanced farther westward as only the finer materials could be carried into the deeper waters. Ice-borne boulders are also found scattered through the formation at all horizons. These were carried by the ice that floated down the principal streams. The cold climate which prevailed during the Sunderland period seems to indicate the contemporaneity of the Sunderland period with the glacial epoch. It has, however, thus far not been possible to correlate the different periods of ice advance with the several Pleistocene formations of the Atlantic Coastal Plain.

After the deposition of the Sunderland formation the country was again elevated above ocean water, and erosion began to tear away the Sunderland terrace. This elevation, however, was not of long duration, and the country eventually sank below the waves again. At this time the Wicomico sea repeated the work which had been done by the Sunderland sea, depositing its materials at a lower level and cutting its scarp line in the Sunderland formation. At this time there was also a contribution of ice-borne boulders which were deposited miscellaneously over the bottom of the Wicomico sea, although more numerous in the vicinity of the larger streams. These are now frequently found imbedded even in the finer material of the Wicomico formation.

At the close of Wicomico time the country was again elevated and eroded and then lowered to receive the deposits of the Talbot sea. The geological activities of Talbot time were a repetition of those enacted during the Sunderland and Wicomico epochs. The Talbot sea usually cut its scarp line in the Wicomico formation but at times transgressed the latter completely and cut into the Sunderland or the underlying Cretaceous or Tertiary beds. Its

terrace was deposited as a flat bench at the base of this escarpment. Ice-borne boulders are also extremely common in the Talbot formation, showing that blocks of ice charged with detritus from the land, were carried down by the major streams and deposited their load over the bottom of the Talbot sea as the ice melted, in precisely the same manner as during the Wicomico and Sunderland epochs.

Imbedded in the Talbot formation in several places are deposits of dark-colored clay filled with plant remains. The most important one occurs on the Rappahannock River a short distance above Tappahannock. The stratigraphic relation of this and similar lenses of clay occurring elsewhere in the Coastal Plain shows them invariably unconformable on the underlying beds and apparently so with the overlying sands and loams, although all form a part of the Talbot formation. Although the clay lenses seem to represent erosion unconformities, they do not, however, represent an appreciable lapse of time. The clays carrying plant remains are regarded as the lagoon deposits made in ponded areas and gradually buried beneath the advancing beach of the Talbot sea. In these ponds or marshes cypress trees and many marsh plants grew in abundance and their remains now form the vegetable débris found in the clay lenses. As the Talbot sea continued to advance, these marshes were finally covered with deeper water, and deposits of sand and loam continuous with the strata elsewhere were laid down, the line of separation appearing as a line of unconformity.

Recent history.—At the present time the waves of the Atlantic Ocean, of Chesapeake Bay, and of the other large estuaries are at work tearing away the land along their margins and depositing it on a subaqueous platform or terrace. This terrace is everywhere present in a more or less perfect state of development and closely resembles the earlier terraces. The materials which compose it are variable, depending both on the detritus directly carried down from the land to the sea and on the currents which sweep along the shore. On an unbroken coast the material has a local character while in the vicinity of river mouths the terrace is composed of débris contributed by the entire river basin.

Beside building a terrace the waves of the Atlantic Ocean and of Chesapeake Bay and its tributaries are cutting sea cliffs more or less pronounced along their coasts. The height of these cliffs depends not so much on the force of the breakers as on the relief of the land against which the waves beat. A low coast line yields a low sea cliff and a high coast line a high one. The one passes into the other as often and as suddenly as the topography changes so that as one sails along the shore of the Bay or estuaries high cliffs and

low depressions are passed in succession. The wave-built terrace and the wave-cut cliff are constant companions along the entire extent of the bodies of tidal water.

In addition to these features, bars and spits are frequently noticed. If the present coast line were elevated slightly, the subaqueous platform which is now building would appear as a well-defined terrace of variable width with a surface either flat or gently sloping toward the deeper channels. This surface would everywhere fringe the Atlantic and Bay shores, as well as those of the estuaries. The sea cliff would at first be sharp and easily distinguished but with the lapse of time the less conspicuous portion would gradually yield to the leveling influences of erosion and might finally disappear altogether. Erosion would also destroy in a large measure the continuity of the terrace but as long as portions of it remained intact the old surface could be reconstructed and the history of its origin determined.

PHYSIOGRAPHIC RECORD

The history of the development of the topography as it exists to-day is not a complicated one. It has been formed at several different periods during all of which the conditions must have been quite similar. It is merely the history of the development of the four plains already described as occupying different levels and of the present drainage channels. The plains of the Virginia Coastal Plain are all plains of deposition which have been more or less modified by the agencies of erosion. Their formation and subsequent elevation to the height at which they are now found indicate merely successive periods of uplift and depression. The drainage channels have throughout most of their courses undergone many changes. Periods of cutting have been followed by periods of filling and the present valleys and basins are the results of these opposing forces.

Lafayette stage.—Within the borders of the Coastal Plain there is evidence of frequent changes during Mesozoic and early Tertiary time which resulted in the deposition of a succession of formations of varying materials. These, however, have been only to a very slight extent influential in producing the present topography. Many of the larger streams evidently occupied their present channels in the Piedmont Plateau during these periods, but their lower courses through the Coastal Plain were obliterated. Even in the early Cretaceous we find that the Coastal Plain deposits formed near the present stream courses consist of much coarser materials that the deposits formed over the divides. In the discussion of the physiographic history of the region as shown by the present topography, the changes which occurred during these periods may be omitted. Towards the close of the Tertiary, however, a change in conditions occurred which is clearly shown in the existing topography. A layer of gravels, sands, and clays was spread over the entire Coastal Plain and on the borders of the Piedmont Plateau during the Lafayette submergence. These deposits must have been laid down on a rather irregular surface, resulting in a comparatively thin mantle of materials 25 to 30 feet in thickness. When the uplift had terminated Lafayette deposition, a very even, gently sloping plain extending from the Piedmont Plateau to the ocean, bordered the continent. Across this plain composed of coarse and fine unconsolidated materials, streams having their sources in the Piedmont Plateau, gradually extended their courses, while new ones entirely confined to the Coastal Plain were

also developed. At this time the shore-line seems to have been farther to the east, and the present submerged channels of the continental shelf were probably eroded during this interval. The Coastal Plain portion of the Delaware River with its extension as Delaware Bay; the Chesapeake Bay and the tidal portions of the Potomac, Rappahannock, York, James, as well as many smaller streams date from this post-Lafayette uplift. The attitude of the subsequent deposits makes this evident, for the Sunderland, Wicomico, Talbot, and Recent terrace formations surround, and in all cases slope toward these various water ways. The Lafayette formation was cut through in most places by the streams, and valleys were opened up in the older deposits, several of which became many miles wide before the corrasive power of the streams was checked by the Sunderland submergence.

Sunderland stage.—As the Coastal Plain was depressed during the early Pleistocene, the ocean waters gradually extended up the river valleys and then over the lower-lying portions of the stream divides. The waves working on the Lafayette-covered divides, removed the mantle of loose materials and either deposited the débris farther out in the ocean or dropped it in the estuaries produced by the drowning of the lower courses of the streams. Sea cliffs produced on points exposed to wave action were gradually pushed back as long as the sea continued to advance. These now represent the escarpments separating the Sunderland from the Lafayette. The materials which the waves gathered from the shore, together with other materials brought in by the streams, were spread out in estuaries and form the Sunderland formation. The tendency was to destroy all irregularities produced during the post-Lafayette erosion interval. In many places undoubtedly old stream courses were obliterated but the channels of the larger streams, while in some cases entirely filled, were in the main left lower than the surrounding regions. Thus in the uplift following Sunderland deposition the larger streams practically reoccupied the same channels they had carved out in the preceding erosion period. They at once began to clear their channels and to widen their valleys so that when the next submergence occurred the streams were cutting as before in Tertiary and Cretaceous materials. On the divides, also, the Sunderland was gradually undermined and worn back.

Wicomico stage.—After the Coastal Plain had been above water for a considerable interval a gradual submergence again occurred permitting the ocean waters to encroach on the land. This submergence seems to have been about equal throughout the Coastal Plain. The sea did not advance

upon the land as far as it had during the previous submergence. The waves beat against the shores and in many places cut cliffs in the deposits that had been laid down during the former period and occasionally removed the entire width of the Sunderland terrace. Throughout many portions of the Coastal Plain at the present time these old sea cliffs are still preserved as escarpments, frequently 10 to 15 feet in height and occasionally much higher. During this time perhaps about one-half of the Coastal Plain of Virginia was submerged. The Sunderland deposits were largely destroyed by the advancing waves and redeposited over the floor of the Wicomico sea. Those portions of the Sunderland lying above 90 to 100 feet were not submerged and for the most part were not destroyed. Deposition of materials brought in by the streams from the adjoining land also took place.

During the Wicomico submergence deposition was effective in destroying a great many of the irregularities which had previously existed as shown by the great depth of the deposits formed in the erosion depressions. Many of the submerged stream channels were entirely silted up, yet the deposits were seldom thick enough to fill entirely the channels and valleys of the larger streams. Accordingly in the uplift following Wicomico deposition, the major streams reoccupied their former channels with perhaps only slight changes. New streams were also developed and the Wicomico plain was more or less dissected along the stream courses, the divides being at the same time gradually narrowed. This erosion period was terminated by the Talbot submergence which carried part of the land beneath the sea and again drowned the lower courses of the streams.

Talbot stage.—Talbot deposition did not take place over as extensive an area as had that of the Wicomico. It was confined to the old valleys and to the low stream divides where the advancing waves destroyed the Wicomico deposits. The sea cliffs were pushed back as far as the waves advanced and now standing as escarpments mark the boundaries of the Talbot sea and the Talbot estuaries. This is the Talbot-Wicomico escarpment previously described. In some places the deposits were so thick in the old stream channels that the streams in succeeding period of elevation and erosion found it easier to excavate new courses. Generally, however, the main streams reoccupied their former channels and renewed their corrasive work which had been interrupted by the Talbot submergence. The Talbot plain has now in many places been rendered quite uneven by recent erosion yet it is less irregular than the remnants of the Lafayette, Sunderland, and Wicomico plains which have been subjected to denudation for a much longer period of time.

Recent stage.—The land probably did not remain stationary with respect to the sea level long before another downward movement was inaugurated. This last submergence is probably still in progress. Before this subsidence occurred probably most of the important rivers, like the Potomac, Rappahannock, and James, were streams of varying importance lying above tide and emptying into the diminished Chesapeake Bay. Whether this downward movement will continue much longer cannot of of course be decided but there is evidence in many places throughout the Coastal Plain to show that this movement has been in progress within very recent time and in all probability still continues. Many square miles that had been land before this subsidence commenced are now beneath the waters of the Chesapeake Bay and its estuaries and are receiving deposits of mud and sand from the adjoining land.

ECONOMIC PRODUCTS OF THE VIRGINIA COASTAL PLAIN

BY

THOMAS LEONARD WATSON.

INTRODUCTION.

There occur within the Coastal Plain region of Virginia, numerous deposits of very considerable economic value. Some of these have been and are still being utilized, while others have scarcely commenced to be developed as yet. Not in a single instance, however, is the production of those products which have been utilized in any wise commensurate with the possibilities. The deposits of clay, sand and gravel, diatomaceous earth, calcareous (shell) and greensand marls, are very extensive and are generally of good grade. The extensive deposits of calcareous (shell) marl and clay, located directly on deep tidewater, offer large possibilities in the location of plants for the manufacture of Portland cement. The potentialities of the economic aspects of the geology of the Virginia Coastal Plain cannot be discussed at length in this chapter, but they are briefly summarized in the discussion that follows below.

DISCUSSION OF INDIVIDUAL PRODUCTS.

The more important of the economic products occurring in the Virginia Coastal Plain region are clays, sand and gravel, diatomaceous earth, greensand marl, calcareous (shell) marl, mineral paint, iron ore, building stone, peat, soils, and underground waters. These are discussed below in the order named.

CLAYS.

Clays have wide distribution over the Virginia Coastal Plain region. They are sedimentary clays, and are usually of unconsolidated character. Almost every formation in the region contains deposits of clay which are suitable for the manufacture of common brick, while the others are adapted to the higher grades of building brick, drain tile, hollow ware, and the cheaper grades of pottery.

The principal clay-bearing formations in the Virginia Coastal Plain are the Nanjemoy, Calvert, Lafayette, Sunderland, Wicomico, and Talbot. The Nanjemoy contains the compact pink or white clays previously described as occurring in the vicinity of Fredericksburg, and in the region south of Stafford Courthouse, where they form promising outcrops, but have not yet been developed. The Calvert contains a great deal of sandy blue clay which is found covering an extensive area in the western portion of the Coastal Plain. These clays are best known south of Richmond, in the vicinity of Curle's Neck, and Bermuda Hundred. This same formation also carries extensive beds of diatomaceous earth or clay, which is well exposed at Richmond and along the Rappahannock River.

The surface loams of the Lafayette, Sunderland, Wicomico, and Talbot formations have also been used largely in various parts of Tidewater Virginia about Alexandria, Fredericksburg, Petersburg, Emporia, Suffolk, Norfolk, Hampton, etc. Lying at the surface they can easily be worked as it is only necessary to remove a few inches of the soil. Sometimes this clay loam is used when only a little more than a foot in thickness but usually beds of not less than three or four feet in thickness are worked. At times the beds attain considerable thickness, as for example near the reservoir west of Richmond where the Lafayette clay loam is about 18 feet thick. More or less gravel and boulders occur distributed through the loams either in the form of isolated pebbles or as lenses or definite layers. These clays, Pleistocene chiefly, occur as more or less basin-shaped deposits widely scattered over the Coastal Plain region.

Nearly all of the clay deposits noted in the Coastal Plain region, whatever their geological age, are of lenticular or lens-shaped character. The majority of them are red-burning, while only a few are buff-burning. No white-burning clays have thus far been found, but even though they lack in variety, so far as their color-burning qualities are concerned, it is probable that their possible uses are more numerous than is now supposed.

The amount of clay suitable for the manufacture of common brick throughout the Coastal Plain is almost unlimited, and the distribution of the deposits is such that brick sufficient for local consumption can be made in almost every neighborhood. It is difficult to understand why these clay deposits have not been more extensively utilized hitherto. Practically no attempt has been made to use the higher grade clays at any point.

The results of a study of the Virginia Coastal Plain clays, including physical tests and chemical analyses, by Dr. Heinrich Ries in 1905, are embodied in the table opposite page 225.

PHYSICAL TESTS AND CHEMICAL ANALYSES OF THE COASTAL PLAIN CLAYS IN VIRGINIA

Laboratory No.	Color	LOCALITY	Per ct. water required for mixing	Slaking	Plasticity	Grit	Per cent. air shrinkage	Average Tensile strength pounds per square inch	Cone 010 Fire shrinkage	Cone 010 Color	Cone 010 % Absorption	Cone 05 Fire shrinkage	Cone 05 Color	Cone 05 % Absorption	Cone 03 Fire shrinkage	Cone 03 Color	Cone 03 % Absorption	Cone 1 Fire shrinkage	Cone 1 Color	Cone 1 % Absorption	Cone 3 Fire shrinkage	Cone 3 Color	Cone 3 % Absorption	Cone 5 Fire shrinkage	Cone 5 Color	Cone 5 % Absorption	Cone 8 Fire shrinkage	Cone 8 Color	Cone 8 % Absorption	Loss on Ignition	Silica, SiO_2	Titanium Oxide TiO_2	Ferric Oxide Fe_2O_3	Alumina, Al_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O	Total Fluxes	Laboratory No.
1300	Yel. buff	Brick mixture, Maynard & Powers, Richmond	20.9	Mody.fast	Good	Fine	6.4	89.6	.0	Lt. red	17.40	1.6	Lt. red	15.08	1.6	Lt. red	14.06	5.	Red	7.1	6.3	Dk. red	4.04	6.6	Gr. br'n	1.4	6.3	Red br'n	1.29	4.61	71.50	1.44	4.78	13.86	.56	.11	2.29	0.81	[illegible]	1300
1302	Yel. buff	Fort Lee	24.2	Mody.fast	Good	Little	8.6	60.6	.0	Lt. red	20.2	1.6	Lt. red	17.6	4.	Lt. red	14.06	6.3	Lt. red	7.5	7.	Lt. red	5.9	8.3	Dk. red	2.6	7.3	Deep br.	1.10	5.52	69.55	1.06	6.05	15.79	Tr'ce	.08	1.54	0.38	[illegible]	1302
1305	Gray blk.	Two miles south of Chester	25.3	Fast	Low	Some	9.3	177.3	.0	Lt. red	18.2	1.3	Lt. red	14.2	1.6	M. red	12.	2.3	M. red	7.54	Vis.	Dk. red	7.65	Vis.	Dk. red	Fus'd	.0	----------	-----	4.41	69.74	.06	6. *	12.64	1.46	1.18	2.54	0.92	13.15	1305
1306	Yel. buff	One mile northwest of Bermuda Hundred	29.7	Fast	Good	Very fine	8.6	148.8	.3	Lt. red	22.04	5.7	Lt. red	12.9	7.	Lt. red	8.7	10.7	Dk. red	.12	10.3	Dk. red	.11	4.6	Gray	2.11	6.6	Dk. red	1.39	5.32	61.83	.08	6.85	21.26	.38	.78	2.44	1.01	11.46	1306
1307	Yel. buff	Keeler's yard, Broadway, on Appomattox River	24.6	Slow	Good	Very little	9.0	138.1	.3	Lt. red	17.9	5.0	Lt. red	10.40	6.3	Lt. red	7.3	8.	Red	1.7	9.3	Dk. red	1.8	7.	Red gray	1.7	7.6	Red br'n	.50	6.67	59.59	.12	8.07	21.10	.20	.76	2.38	1.06	12.47	1307
1311	Yel. buff	Sturgeon Point	23.1	Mody.fast	Good	Fine	7.6	122.6	.0	Lt.red	16.8	2.3	Lt. red	11.9	3.	Red	8.2	5.6	Red	3.9	7.	Dk. red	1.9	5.3	Dk. red	1.5	5.6	Dk. red	1.07	4.53	68.60	.16	6.41	16.11	.75	.32	2.35	.71	10.54	1311
1312	Gray	Oldfield	20.3	Slow	Good	Much	7.6	111.5	.0	Pink buff	16.3	1.6	Pink buff	15.04	2.	Pink buff	13.6	3.6	Yel. red	7.2	6.	Pk. buff	3.9	6.6	Gray	1.08	7.3	Drab	1.57	2.81	73.84	1.22	3.39	15.08	.62	.12	2.17	.71	7.01	1312
1313	Buff	Oldfield	23.1	Mody.fast	Good	Little	8.6	191.0	.3	Lt. red	17.5	1.6	Lt. red	14.8	4.	Lt. red	9.6	6.3	M. red	5.5	7.	M. red	4.9	7.6	Dk. gray	1.68	5.	Drab	1.10	5.34	68.97	1.28	4.22	16.51	.44	.05	2.59	.56	7.86	1313
1314	Yel. buff	Ball property six miles south-east of Richmond	20.9	Mody.fast	Good	Little	7.4	134.8	.0	Lt. red	17.7	4.7	Lt. red	10.1	6.	Lt. red	7.02	8.3	Red	1.5	7.6	Dk. red	.4	3.	Dk.r.br.	2.6	s.s.	Dk. red	1.02	4.10	65.97	1.04	6.74	17.38	1.16	.17	2.46	.93	[illegible]	1314
1315	Yel. buff		23.1	Mody.fast	Good	Little	7.3	126.7	.0	Lt. red	19.5	3.	Lt. red	14.8	4.3	Lt. red	13.1	9.0	M. red	2.5	8.6	Dk. red	1.01	7.	Gray	.7	7.	Red br'n	.55	5.41	63.82	Tr'ce	6.32	20.44	.22	.11	2.72	.93	[illegible]	1315
1316	Lt. gray		24.2	Mody.fast	Excellent	Little	8.6	135.1	.0	Pk. cream	16.03	4.3	Pink buff	9.2	5.	Buff	4.7	6.5	Gray buff	.09	7.	Gray buff	.07	7.	Drab	.14	s.s.	Drab	.90	4.82	66.01	.50	3.59	20.77	.92	.11	2.52	.74	7.88	1316
1322	Br. buff	Impure diatomaceous earth, Richmond	31.6	Fast	Lean	Some	13.		.6	Lt. red	14.62	.6	Lt. red	13.6	2.	Lt. red	12.42	3.	Lt. br'n	9.1	3.3	Red br'n	6.9	5.	Red gray	5.06	2.	Brown	2.04	5.21	70.42	.44	5.17	15.15	.14	.79	2.24	.39	[illegible]	1322
1323	Buff		34.6	Fast	Lean	Some	14.		.6	Lt. red	14.9	2.3	Lt. red	10.9	3.3	Lt. red	9.	5.	M. red	4.16	6.	M. red	2.30	6.	Red gray	1.70	5.6	Red gray	1.09	6.39	63.17	.88	6.32	19.30	.06	.69	2.45	.69	10.21	1323
1324	Yel. buff	W. J. Ready's yard, Manchester, by Richmond	20.3	Mody.fast	Good	Sandy	7.	93.7	s. s.	Lt. red	15.5	1.3	M. red	12.9	1.6	M. red	11.4	3.7	Dk. red	6.2	5.3	Dk. red	3.4	5.	Dk. red	1.4	5.5	Dr.r.br'n	.19	4.03	73.38	N'ne	5.53	13.53	.58	.14	2.32	.47	9.04	1324
1325	Brown		20.3	Mody.fast	Good	Much	6.	132.	s. s.	Lt. red	17.5	2.	Lt. red	16.8	2.6	M. red	12.07	3.6	Dk. red	9.8	4.	Dk. red	8.7	5.	Dk. red	6.29	Vis.	Red br'n	1.47	4.85	69.43	N'ne	6.70	14.79	.57	.63	2.26	.71	10.87	1325
1326	Br. buff		18.7	Fast	Fair	Sandy	6.	99.	s. s.	Lt. red	16.4	.6	M. red	15.1	1.	M. red	14.4	2.	M. red	10.3	3.	Dk. red	8.2	5.6	Red	1.6	.6	Red br'n	1.00	3.65	72.61	.44	5.61	13.08	.96	.23	2.45	.93	10.15	1326
1330	Gray	Williamsburg road, near Stagg's Mill, Richmond	27.8	Slow	High	Some	12.6	300.9	1.	Pink	14.4	3.	Pink	8.9	5.	Lt. red	5.65	7.6	Red br'n	1.07	7.6	Dk. br'n	.08	2.	Gray	2.4	3.	Drab	1.56	5.29	63.06	.04	6.26	20.90	.16	.45	3.13	.68	10.68	1330
1331	Br. buff	Turner's yard, near Petersburg	23.1	Slow	Excellent	Little	8.	135.5	.3	Lt. red	17.09	2.	Lt. red	15.30	3.6	Lt. red	11.80	4.6	M. red	7.8	5.	M. red	8.7	7.6	Dk. red	3.	6.3	Dk. red	1.30	7.25	61.35	.06	7.10	19.70	.67	.34	2.38	1.11	[illegible]	1331
1333	Lt. brown	Wood's yard, near Emporia	24.0	Slow	Good	Little	8.6	132.4	.3	Lt. red	16.30	1.	Lt. red	13.70	2.7	Lt. red	11.90	3.	M. red	11.05	3.6	Dk. red	9.9	4.3	Dk. red	6.20	6.	Dk. red	1.08	6.09	67.14	N'ne	6.21	16.18	1.19	.11	1.95	[illegible]	[illegible]	1333
1334	Lt. brown	Clays showing variable character of upper bed at Sturgeon Point	24.2	Mody.fast	Fair	Sandy	8.3	144.2	.3	Lt. red	17.7	1.6	Lt. red	14.7	3.0	Lt. red	12.1	4.3	M. red	8.2	5.	Dk. red	6.6	4.6	Dk.r.gray	5.	5.	Red br'n	.21	5.07	69.75	.06	4.67	17.13	.53	.31	1.89	.56	[illegible]	1334
1335	Gray		18.7	Fast	Fair	Much	6.	105.1	.0	Pink	15.7	.3	Pink	14.5	1.3	Lt. red	12.2	1.3	Lt. red	10.3	2.6	Mot. red	9.3	2.3	Lt. red	7.86	3.6	Lt. br'n	.31	3.03	74.55	.22	3.07	15.43	.43	.65	1.42	1.16	6.73	1335
1336	Gray		18.7	Fast	Low	Sandy	5.	79.8	s. s.	Pink	15.08	s. s.	Lt. red	14.4	.0	Lt. red	13.9	.0	M. red	12.90	7.	Lt. red	12.3	.0	Dir.lt.red	10.91	1.3	Lt. br'n	6.50	3.24	77.78	.20	3.05	12.84	.40	.29	1.69	.44	5.87	1336
1336a	Gray	Clay from river level, Sturgeon Point	30.2	Mody.fast	Fair	Little	8.	118.7	.3	Blu'h. red	20.54	2.	Lt. red	15.9	5.3	Lt. red	9.81	8.3	Dk. red	2.80	.0	Dk. red	1.5	8.6	Dk. red	.15	7.	Dk. red	.04	7.49	61.21	Tr'ce	5.81	20.82	.57	.75	2.57	.73	10.43	1336 a
1339	Br. buff	City Point	20.3	Slow	Excellent	Much	7.6	155.	.6	Lt. red	17.2	3.3	Lt. red	11.5	4.	Lt. red	10.05	6.	M. red	4.6	6.3	Dk. red	2.7	6.6	Dk. red	1.3	6.6	Dk. red	1.52	7.76	61.06	.16	7.03	19.61	.77	.09	2.34	1.01	11.24	1339
1343	Gray	Standard Brick Co., south of Suffolk	22.	Slow	Excellent	Much	8.6	144.6	s. s.	Pinkish	14.6	1.6	Pinkish	13.6	1.6	Buff	12.6	1.6	Lt. red	10.9	2.3	Lt. red	9.7	3.	Lt. yellow	7.01	3.3	Lt. br'n	3.60	5.06	75.79	Tr'ce	3.17	14.85	.04	.08	.75	.22	4.26	1343
1344	Drab	Blue clay, Suffolk Clay Co., Suffolk	31.9	Slow	Excellent	Little	11.6	143.8	1.3	Pink	16.9	4.	Pink	8.87	5.6	Lt. red	6.11	7.	Lt. br'n	1.50	7.6	Drab	.20	B'd vitri	Lt. gray	Bey'nd vitri	.0	Drab	-----	6.66	64.39	.08	4.40	20.49	.17	.91	2.31	.54	8.33	1344
1345	Buff	Brick mixture, Suffolk Clay Co., Suffolk	26.4	Slow	Good	Little	10.3	142.5	.6	Pink	15.4	3.	Lt. red	10.6	3.6	M. red	7.5	6.6	M. red	2.6	7.3	Dk. red	1.04	7.	Gray	.60	5.	Red drab	.02	5.98	65.55	1.95	5.29	18.13	.39	.51	1.82	.33	8.34	1345
1350	Pink	Eocene clays from between Stafford C. H. and Fredericksburg	36.3	Mody.fast	Crumbly	Little	9.3	115.3	.6	Lt. red	28.2	2.6	Pink	23.1	3.6	Lt. red	14.20	7.	Lt. red	12.06	9.	Lt. red	7.91	10.3	Red br'n	3.50	10.3	Red br'n	3.74	8.63	51.12	.47	10.70	26.14	.10	.25	1.78	.77	12.87	1350
1352	White		35.2	Mody.fast	Good	Little	8.6	113.7	.6	Pk. white	25.4	.0	----------	-----	2.6	Cream	19.6	5.	Cream	13.2	6.3	Lt. yel.	13.1	7.6	Yel. buff	8.30	10.	Drab	2.49	8.44	57.26	.14	3.10	28.97	.04	.19	1.40	.42	5.15	1352
1353	Yel. br'n	Between Milford and Bowling Green	27.5	Mody.fast	Good	Little	11.	193.6	.3	Lt. red	16.6	2.	Lt. red	13.3	2.	Red br'n	11.79	4.	M. red	9.70	4.3	Dk. red	5.32	5.	Red br'n	2.09	5.	Red br'n	2.02	5.09	69.00	.10	6.72	15.58	.06	.15	2.34	.91	10.18	1353
1354	Gr'n gray	One mile south of Layton	24.2	Slow	Low	Much	6.	41.2	s. s.	Lt. red	26.80	.0	Lt. red	27.5	.3	Lt. red	27.77	1.	Lt. red	27.	1.6	Red	25.5	2.	Lt. br'n	27.9	2.3	Red	24.79	3.55	85.72	.06	1.74	5.83	1.01	.11	1.31	.64	4.81	1354
1356	Light red	Red clay, northwest of Fredericksburg	33.0	Fast	Good	Little	9.6	79.9	.6	Lt. red	28.01	4.	Lt. red	21.70	6.	M. red	15.40	11.	Dk. red	4.08	12.3	Dk. red	1.4	12.6	Dk. red	.18	13.3	Dk. red	.02	6.00	55.33	.81	9.02	25.69	.22	.08	2.57	.25	12.14	1356
1358	Light red	Diatomaceous earth, one mile south of Layton	23.1	Fast	Low	Little	10.3	29.4	.6	Lt. red	21.73	.6	Lt. red	20.70	2.3	Lt. red	15.88	5.6	Pink	11.3	5.6	Red gray	9.5	6.	Lt. br'n	5.4	6.3	Lt. br'n	2.57	3.66	78.82	.33	5.42	9.24	.04	.12	1.51	.81	[illegible]	1358
1362	Lt. brown	Pleistocene clay, Wilmont	19.2	Mody.fast	Good	Some	7.3	130.8	.0	Lt. red	12.84	.0	----------	12.0	1.	Lt. red	10.30	2.6	Lt. red	8.5	2.3	Lt. br'n	6.1	3.	Lt. red	5.9	4.3	Br. red	2.03	4.74	71.60	1.88	4.65	13.18	.42	.66	1.58	1.23	8.54	1362
1363	White	Diatom earth, Wilmont	62.4	Fast	Low	Some	3.6	34.4	1.3	Yell'wish	50.96	1.6	Lt. pink	48.4	1.	Lt. pink	44.00	4.6	Pk. cream	41.4	4.6	Yellow	40.9	5.3	Yellow	38.3	5.6	Yel. br'n	32.32	3.40	82.85	1.09	2.34	6.76	.35	1.06	1.07	.99	5.81	1363
1365	Buff	Clay from "House" bank south-east of Wilmont	22.0	Mody.fast	Good	Much	7.6	87.1	s. s.	Pk. cream	15.2	.0	Pk. crean	14.4	.3	Pk. cream	14.01	1.3	Yel. br'n	12.22	1.6	Br. yel.	10.72	1.3	Red yel.	11.2	2.3	Red yel.	9.87	4.59	77.28	.06	2.42	13.01	N'ne	.70	1.22	.68	5.02	1365
1367	White	Sandy clay, Occupacia P. O.	26.4	Fast	Fair	Sandy	8.6	54.2	.0	Lt. red	29.89	.6	Lt. red	28.3	1.6	Lt. red	27.72	2.	Pink	23.34	2.3	Lt. red	23.7	2.6	Yel. br'n	21.05	5.	Brown	19.	3.06	84.64	.24	2.59	7.73	.10	.17	1.12	.32	4.30	1367

*FeO, 1 per cent.
s.s. Slightly swelled.
The chemical analyses in this table were made by Messrs. J. R. Eoff, Jr., and J. H. Gibboney.

DESCRIPTION OF CLAY AREAS.[a]

The Alexandria Area and Vicinity.

This area is the most important brick-making district in the Virginia Coastal Plain region. It cannot be said that this marked local expansion of the clay-working industry is due to the more abundant occurrence of clay at this point, but rather to the fact of its nearness to an active and important market, namely, the city of Washington. Nearly all the brick yards of this area are situated so close to the city, that the product is hauled across the river by teams, and the daily continuous procession of wagons loaded with brick indicates the demand for the Virginia product.

The clays used in the Alexandria district are the Columbia loams, which underlie the low hills around Alexandria, Arlington, Addison, Riverside, etc. They are all sandy loams of variable color, yellow, red, brown, and bluish-gray, and are frequently of a mottled character. Most of the clays burn to a red brick, but certain ones show a tendency to fire buff, and since these lighter burning parts are oftentimes tougher, they do not mix readily with the red-burning clay when the run of the bank is used, so that the buff spots show in the brick after burning. At the yard of the Washington Hydraulic Pressed Brick Company, the several clays are carefully separated and burned alone, thus giving several different shades of product.

The firms in operation in this region are: Washington Hydraulic Pressed Brick Company; Jackson-Phillips Company; Potomac Brick Company; Virginia Brick Company; Estate of Charles Ford; Walter Brick Company; West Brothers; Alexandria Brick Company; Washington Brick and Terra Cotta Company; and American Hygienic Brick and Tile Company. The last is located near Riverside.

The Fredericksburg Area.

The most prominent clays in the region around Fredericksburg are those belonging to the Eocene formation. While these no doubt underlie a considerable area between Fredericksburg and Stafford to the north, still prominent outcrops of them are not very abundant.

The nearest of these to Fredericksburg is located along the road from Fredericksburg to the Cartwright and Davis granite quarry on the hill leading up from the canal. This material, which is of a bright red color, is known, locally, as paint clay, and is said to have been used by the Indians

[a]Abstracted from chapter on clays in Mineral Resources of Virginia, 1907.

for that purpose. How extensive the bed is can only be determined by boring, for no outcrops of it are seen, except along the road, but there it is exposed in the ditch at the roadside for several hundred feet at least. Tests of this clay (No. 1356) are given in the appended table, facing page 225.

Following the road from Fredericksburg to Stafford, there are a number of indications of bluish-white Eocene clay in the ditches along the roadside but most of these are topped by a heavy bed of sand. About 6 miles east of north from Fredericksburg, a heavy bed of the clay is found on top of a ridge.

The section here involves:

	Feet
Surface sand and soil	1-2
Pink clay, laminated	12
Whitish clay	4

The pink clay (Lab. No. 1350) is distinctly stratified and in its upper part contains some scattered crusts of limonite. The physical and chemical properties of this clay are given in the table opposite page 225.

The clay, although burning to a good color, is not a dense-burning one; in fact, it does not yield as tight a body as some of the Pleistocene clays. Its main use should be for common brick, pressed brick, or drain tile. The outcrop mentioned is somewhat distant from the railroad for cheap exploitation, but the extension of this bed should be found to the westward, nearer lines of transportation.

The whitish clay (Lab. No. 1352), which underlies the pink clay, is of buff-burning character and burns to a good body. It would no doubt make a good light-colored pressed brick by either the wet method repressed, or the dry-press process. Its analysis and physical tests are given in the table opposite page 225.

The Wilmont Area.

This is practically the only locality along the Rappahannock River where the Pleistocene clays are worked, and the quality of those developed at this point would make it seem desirable to prospect further for other deposits.

At the brick works at Wilmont the following section is exposed:

	Feet
Soil	1
Blue clay (so-called)	5-6
Gravelly sand (variable thickness)	6-15
Diatomaceous earth	10
Greensand clay	4

The blue clay, which is of Pleistocene age, is mixed with either the diatomaceous clay, or with clay from another surface deposit not far distant. The green sandy clay, which is the same as that tested from Layton, lies below the level of the yard.

Another deposit of Pleistocene clay, known as the House clay, is dug about one-fourth mile northeast of the brick works. Here the clay runs from 9 to 13 feet in thickness and is underlain by sand. Still another deposit has been located one-half mile northwest of the brick yard. Only the House clay (Lab. No. 1365) and that at the brick yard (Lab. No. 1362) were tested. Their properties are given in the table opposite page 225.

Although these clays are both surface clays, and occur in the same formation at no great distance from each other, still they are quite dissimilar in many respects.

No. 1362 is a red-burning clay which burns to a good bright color. Its air shrinkage is not excessive and its fire shrinkage is low. It contains some coarse grit which shows up clearly on the fractured surface of the burned bricklet. At cone 8 portions of the clay become viscous. This is not a fire clay, but it works well for brick and fireproofing.

No. 1365 is a gritty, light-burning clay which does not burn steel-hard until cone 5, and even at 8 still shows a rather high absorption. Its low air shrinkage and low tensile strength are characteristic of sandy clays. The material can be classed as a low-grade fire clay, such as is used in terra-cotta manufacture, or for boiler-setting brick. It is the most refractory of the series tested from the Coastal Plain area.

The brick works at Wilmont produce fireproofing, boiler-setting brick, and some front brick. In each case a mixture of the Pleistocene clays, or of these with diatomaceous earth, is used.

The Layton Area.

Along the shore of the Rappahannock River, about 1 mile south of Layton, there is a long outcrop of gritty greenish clay, of Miocene age, which is evidently part of a rather extensive deposit. The material is well shown in the river bluff, and its smooth vertical surface stands out in marked contrast to the overlying sand. The bed as here exposed is not less than 9 feet thick, and is overlain by 6 to 8 feet of sand, which may be adapted to molding purposes. The clay (Lab. No. 1354) in table opposite page 225, evidently underlies the diatomaceous earth which crops out farther down the

river, and both are overlain by the sand referred to above. This same clay is seen inland from the river, behind the mill at Occupacia post-office; it also underlies the diatomaceous earth at Wilmont, and is seen at several other points along the river bank.

It is exceedingly sandy, as can be told by the feel, and seen from the analysis (silica, 85.72 per cent.). Its shrinkage is very low and it burns to a very porous body, so that it would seem undesirable to use it for even common brick.

Overlying this at Occupacia post-office is a whitish sandy clay (No. 1367) of table opposite page 225, which, although quite different in appearance from the green clay, resembles it closely in both physical and chemical properties. One might suppose, judging from its color, that it was a fire clay or at least semi-refractory in its character, but it is not.

The Milford Area.

Along the road from Milford to Bowling Green, and about three-quarters of a mile from the former locality, there is a promising deposit of yellowish brown Pleistocene clay, 10 to 12 feet thick. The bed is underlain by sand, but has very little overburden. Its characters are given in the table opposite page 225 (No. 1353).

This is a red-burning surface clay, which becomes steel-hard at 03, but is too gritty to use for any purpose except common-brick manufacture. It would probably work on a dry-press machine.

The Richmond Area.

Richmond, next to Alexandria, is the most important clay-working center in the Coastal Plain region, there being a number of yards engaged in the manufacture of common and in some cases pressed brick. Most of these are located on the edge of Richmond and in the suburbs of Manchester and Fulton, while a few are located near the reservoir and race track.

The output of these is not sufficient to supply the demand, and some outlying towns are also drawn upon. The better grades of pressed brick in Richmond are not made in the Coastal Plain area. Some are obtained from Clayville, Powhatan County, Virginia, but most of them come from points outside of the State.

There are four yards in operation in Manchester, all of them being located in the vicinity of Knight and Maury streets. All of these are engaged in the manufacture of soft-mud brick and a few of them also

produce a small quantity of pressed brick. The clay used is a more or less mottled, gritty, yellow or reddish clay, which is covered by a thin layer of sandy soil and commonly underlain by a bed of sand. At only one point, namely, the yard of Green and Harrison, is the underlying crystalline rock encountered. The clays in general are very tough and plastic, sometimes quite sandy, and they contain a variable quantity of stony material which ranges in size from small pebbles up to large boulders, most of these being of crystalline character. This stony material is not found to be uniformly distributed through all the beds, but seems to run rather in streaks, the greatest quantity of it having been observed in the bank of W. J. Ready, and Green and Harrison.

At G. E. Redford's yard, the clay shows an average thickness of 12 feet with a maximum of 17 feet, and is underlain by a hard bed of sand and gravel. It is a mottled gritty clay with scattered mica fragments and many limonite stains running through it; and it contains also many decomposed pebbles of crystalline rock. The clay pit is a large shallow excavation lying to the south of the yard and the working face has a height of from 6 to 8 feet. The material is red-burning, and for the manufacture of bricks the run of the bank is commonly used. This is necessary because the clay seems to vary somewhat in its physical character. Thus, for instance, it is not safe to use that found in the north end of the pit alone, because it is very tough and cannot be used without cracking. It is mixed therefore with the more sandy portions of the bed.

Adjoining the yard of Redford on the west is that of W. B. Davis. This pit, which is a large shallow excavation, lies to the south of the yard, and has a working face of from 6 to 7 feet in height. The clay is similar to that in Redford's bank, but seems to contain fewer stones.

Adjoining Davis' yard on the east is that of W. J. Ready. The clay pit which lies to the northwest of the yard is much deeper than the neighboring excavations and also lies at a slightly lower level, for the upper surface of the clay is uneven and slopes towards the river. The clay in general is somewhat similar to that found at the two preceding yards but contains more stones and boulders than are found in either Redford's or Davis' bank. The thickness of the clay is said to be at least 18 feet, and it is probably underlain by sand. Here in a working face of perhaps 200 feet in length they recognize three different kinds of clay, only one of which they claim can be used alone. If either of the other two is used by itself, it results in an imperfect product. The physical and chemical characters of these three clays are given in the table opposite page 225.

A plant is also operated by W. J. Ready near the West End yard and is located a quarter of a mile west of the track near the reservoir. The material is the usual mottled surface clay which is worked to a depth of about 7 feet, although a total thickness of 20 feet is claimed for it.

The yard of the Fulton Brick Company, which is commonly spoken of as Westford's yard, is located west of the Chesapeake and Ohio Railway round house. The clay used here is the ordinary surface clay and does not seem to run over 10 feet in thickness. It also contains many cobble stones. Underlying this is a fine sand which is at least 8 feet deep and is used for sanding the brick molds.

The Baltimore Brick Company operates two yards at Rockett, a suburb of Richmond. The yards are located near the intersection of Ohio and Williamsburg avenues. The clay is tempered in ring pits, molded by hand, and burned in dutch kilns. Some 17 years ago the company tried making soft-mud machine brick but gave it up for some unknown reason. The clay is obtained from under the surface at several points in the vicinity of the yard and averages from 15 to 18 feet in thickness with an underbedding of sand. The material is quite similar in character to that at Manchester, but lacks the stones and boulders.

Maynard and Powers' pit is southeast of the Baltimore Brick Company's excavation. The working face is about 12 feet high and shows a sandy, mottled, yellowish-brown and gritty clay similar to that occurring in the other pits in this vicinity. The company claims that its clay runs 20 feet in depth and is underlain by a bluish-gray sand. The chemical and physical properties of this clay (No. 1300) are given in the table opposite page 225.

A clay very similar to that on the Ball property, 6 miles south of the city, and probably of the same age is also found outcropping on the Williamsburg road leading to Stagg's Mill, about one-half mile to the west of where the road crosses the railroad. The clay is exposed on a sloping hillside, and in such position that a large quantity can be removed without having to take off much overburden. It is also well located for shipment. As far as could be ascertained the bed is not less than 20 feet thick. It (Lab. No. 1330) is a grayish clay, which slakes slowly and works up with 27.8 per cent. water to a mass of high plasticity. Its air shrinkage, 12.6 per cent., is somewhat high; so also is the average tensile strength, namely, 300.9 pounds per square inch.

This is a very plastic clay which becomes steel-hard at cone 05. It gives a light red color up to cone 03, but at cone 1 gives an excellent dark red

color. Its point of vitrification is apparently reached at about cone 3, and at cone 5 it was well passed vitrification and had swelled considerably. It is not as good a clay as that described from near Bermuda Hundred (Lab. No. 1317) or Curle's Neck (Lab. No. 1314).

The Fort Lee Area.

At Fort Lee on the Chesapeake and Ohio Railway, about 2 miles south of Richmond, there is a group of yards operated, respectively, by C. H. Oliver, J. M. Davis, and the Fulton Brick Company. The general run of the clays is not unlike those used around Richmond, but none of the pits show stony material, such as is found in some of the Richmond clay banks.

The most southern of this group of yards is that of C. H. Oliver, which is located one mile west of Fort Lee. The clay is found immediately underlying the surface and the bank shows 12 feet of clay, although the total thickness of it is said to be 20 feet. Underlying it is a pit of gravel and sand of unknown depth. For making bricks the run of the bank is used. The general physical properties of this clay (No. 1302) are given on page 225.

Adjoining Mr. Oliver's yard on the west is that of J. M. Davis. The clay used is similar to that employed at Oliver's pit described above. It is molded by hand, dried on pallets, and burned in dutch kilns. A few hundred feet up the track and on the north side of it are two yards operated by the Fulton Brick Company. The brick yard adjoins the clay bank on the west and the material is practically the same as that seen at the Davis place, but the methods used for winning the clay are more improved.

The dark-colored clays, similar to those described from south Chester, outcrop at several points around the base of Government Hill, especially along the Government road leading down from the top of the hill, but in nearly every instance they are covered with too much overburden to permit of their being profitably worked.

Summary.—It may be well to make a comparative summary of the clays found in the Richmond area. Those found near the city, and those which are worked at Manchester, Fulton, and near the reservoir, are to be classed as good common-brick clays, which burn to a good color, and also make a fair grade of front brick when repressed. They are too gritty and stony as well as too irregular in their character to be used for drain tile, hollow blocks, or red earthenware. The methods used for working them are usually crude, and therefore the yards are of limited capacity. The manufacturers

claim, however, that owing to difficulties with labor, it is impracticable to use more improved methods, such as machine molding. Some also maintain that the hand-molded brick sell better on the local market.

The clays found at Fort Lee appear to be less stony and even less sandy than those occurring at Richmond, and they are susceptible of being worked by more improved methods. Of the yards located at Fort Lee, one used a soft-mud machine, and another a stiff-mud machine. Even these clays, however, are somewhat siliceous for any use other than brick, although it is probable that drain tile or hollow brick could be made from them.

Apparently the best clay in the Richmond area is that described from near Stagg's Mill on the Williamsburg road. This is more plastic, denser burning and less sandy, than any of the clays now being worked either around Richmond or Fort Lee. The deposit being located so close to the city, as well as close to a railroad line, should be investigated by clay manufacturers.

Large areas have already been dug over in the brick-making districts around Richmond, because the deposits are comparatively shallow, and the output of the yards has been large. Each manufacturer naturally excavates the clay nearest to his yard first, so that as year after year goes by the pit face recedes, and the clay haul becomes longer and longer. As the city of Richmond and its suburbs are growing, it will not be many years before building will encroach on the brick yards, and the latter will have to be moved. Being, as it were, temporarily located, there is therefore not much inducement for establishing an extensive plant.

The Curle's Neck Area.

About one mile north of Curle's Neck and 6 miles south of Richmond, there are a number of exposures of clay along the road, and also on the farm on the west side of the road, at a locality pointed out by Mr. W. A. Ball, of Richmond. This material has been usually spoken of as fullers earth, and some sample car-loads have been shipped to cotton oil factories in order to test it for bleaching purposes. The material, however, is very plastic and on inspection one would be likely to form the opinion that it was a clay suitable for the manufacture of some red-burning ware. In fact it is stated that at one time a small stoneware pottery was in operation at this point and there is considerable evidence of this in the numerous fragments of stoneware which are scattered over the field near the farmhouse. Three samples, Nos. 1314, 1315, and 1316 were tested from this locality, the results being given in the table opposite page 225.

The Chester Area.

A number of outcrops of clay are seen in the railroad and trolley road cuts in the vicinity of Chester. None of them, however, are suited to the manufacture of brick. About two miles south of Chester along the Atlantic Coast-Line Railway there are several cuts, which show outcrops of a sandy, bluish fossiliferous clay. The material is not uniform in character, certain layers being highly fossiliferous, others very sandy, and still others very plastic. The exact thickness of the deposit is not known, but from the exposures, it is evidently not less than 30 feet thick. No attempts have been made to use it.

The general characteristics of the clay may be summed up as follows: Red burning, low fire shrinkage, and low fusibility. Difficult to burn. It is not to be recommended for anything but common brick, and even for this purpose it should be avoided if something better can be found.

The Bermuda Hundred Area.

Much clay is exposed at a point along the railroad from Chester to Bermuda Hundred and about 1 mile from the railroad station at the latter locality. The same material is also seen in the gullies in the neighboring fields. This clay is at the same level as that which is worked at Broadway, on the Appomattox River, and it is probable that the deposit extends in that direction, but it does not belong to the same formation.

The exposures in the railroad cut show a thickness of not less than 10 feet, and a thickness of 49 feet was proved by boring in one place. Although the clay along the railroad track does not show much variation on inspection, it is stated that at the northeastern end it is brick clay, while at the southeastern end it is tile clay. The properties of the brick clay (No. 1306) are given in the table opposite page 225.

Judging from the dense body of this material it would be worth experimenting with for paving brick, or perhaps pipe. The most serious objection to it is its high air and fire shrinkage.

This clay has been dug and shipped occasionally to the works of the Powhatan Clay Manufacturing Company, at Clayville, near Richmond.

The Petersburg Area.

There are several yards in operation near Petersburg. Two of these, the W. R. Turner, and Brister and Harrison, are located in Ettricks, across

the river from Petersburg; the third, that of the Chesterfield Brick Company, is situated about two miles from Petersburg near the line of the Petersburg-Richmond trolley road. They all make an excellent grade of red brick. The properties of these clays are given in the appended table opposite page 225.

The clay is molded on a plunger stiff-mud machine, dried on pallets, and burned in scove kilns. The local contractors state that the supply of bricks from the yards around Petersburg is entirely sufficient to meet the demand in that city.

The Broadway Area.

The only brick yard in operation at this locality is that of Keeler and Son, which is located immediately at the foot of the bluff along the Appomattox River. The clay deposit lies about 75 feet above the river and the clay is being dug at a point in the terrace about 300 feet south of the yard. It is a tough, mottled material with a thickness of at least 15 feet, the upper 2 feet of which are weathered. Overlying this are about 18 inches of gravelly sand similar to that which occurs immediately under the surface throughout this region, on both sides of the river. The clay is underlain by a coarse, gravelly sand which extends down to the river level and probably below it.

The clay burns steel-hard at cone 05 and at either this temperature or cone 03 it makes an excellent red brick. If burned to this cone, or better still, to cone 1, the material would probably make a good pressed brick.

This is an excellent red-burning clay which could probably be used for making front as well as common brick, provided it is thoroughly pugged. At the present time it is utilized for making common brick, and the run of the bank is used, leaving out the overburden of gravelly sand.

The City Point Area.

The Pleistocene clays outcrop in the bluff along the James River, about one-eighth mile south of City Point landing. Their distribution is evidently irregular, for in the first cut of the railroad after leaving City Point, there is nothing but sand exposed, although the bottom of the cut is not as high as the upper part of the clay along the river shore. I was informed that borings made to the south of the railroad cut had revealed the presence of the clay under the surface sand. Along the shore the clay is not less than 20 feet thick, but it contains occasional streaks of sand. There are also about 4 feet of sand overburden. No brickyard is located at this point although the deposit is at the water's edge and the product could

be easily shipped. Occasional car-load lots have, however, been dug and shipped to the smoking pipe factory at Pamplin City. As for this line of ware, a small quantity of clay will go a long way, so that the amount that has been dug has produced little impression.

The characters of the clay (No. 1339) are given in the table opposite page 225. Its chief advantage is convenient location for shipment by rail, an advantage not possessed by most deposits along the James River.

The Sturgeon Point Area.

The W. C. Mayo and Sons brick plant is located along the river's edge at the base of the bluff, while the clay is obtained from near the top of the bluff. The section at this point involves:

	Feet
Loam	1 to 2
Clay	7 to 8
Sand	2
Mottled clay with iron streaks	9
Sand	20 to 30
Blue sand	3+

The sand mentioned in the lower part of the section extends down to the river's edge, and at that point it is underlain by a bed of dark bluish-gray, highly plastic clay, which is about 3 feet in thickness. The upper layer of clay was formerly worked and a considerable quantity of it has been dug. The clay was found, however, to be so variable in character and burning qualities that it was undesirable for use, consequently the raw material for the yard is taken from the middle clay bed given in the section, which yields a more uniform product.

It is claimed that this deposit of clay extends more or less continuously for at least twelve miles back from the river.

The Oldfield Area.

This locality lies about four miles south of Sturgeon Point and on the same side of the river. The Oldfield Brick and Tile Company is engaged in the manufacture of common brick. The clay here, as at Sturgeon Point, underlies the terrace which borders the river, and the brick yard is located at the base of the terrace escarpment on the river's edge. It may be said that the materials underlying the terrace consist of dense or alternating beds of sand and clay overburden, and an upper bed of loamy clay underlain by a siliceous clay, which weathers to a whitish color and contains many cylin-

drical limonite concretions. The upper bed has an average thickness of about 3 feet, and this is first removed and utilized for the manufacture of common brick. The under bed seems to vary in thickness, but where best exposed at the south side of the deposit and nearest to the yard, the thickness is at least 7 feet. It is underlain by a tough sandy clay which is not used and which passes downward into a bed of loamy sand containing streaks of pebbles. The two kinds of clay are worked separately, the upper clay being used for common brick, and the lower clay, with the limonite concretions, known as the tile clay, being used for tile or extra hard brick, termed paving brick. A sample of each of these was tested and the tests given in the table opposite page 225.

The Belfield Area.

This town, which adjoins the better known one of Emporia, has one yard, whose product consists entirely of common brick, and which is operated by Dr. Wood, of Emporia. The soil is quite sandy around Belfield, and the surface flat, so that there are very few clay exposures. At the brick yard the clay extends nearly to the surface and averages about 5 feet deep, being bottomed on a coarse, whitish sand, which is not mixed in with the clay, as it does not seem to improve its quality. The clay burns to an excellent red color and makes a good common brick.

The Norfolk Area and Vicinity.

The cities of Norfolk, Portsmouth, and Newport News, are among the most important in the Coastal Plain area of Virginia, and in all, building operations are being carried on quite extensively. There is here consequently a good market for building brick, either common or pressed, and the supply is drawn from a number of points.

There are several yards in the immediate vicinity of these cities which deserve mention. E. W. Face and Son operate a yard on North Avenue, Atlantic City. The raw material is brought from a pit of Pleistocene clay on the Nansemond River, near Suffolk, and in its general character resembles that worked at the brick yards around Suffolk. It is a red-burning clay of excellent plasticity, which yields a good product for structural work. Before molding, the clay has a small quantity of fine coal mixed in with it, to help in burning, a practice somewhat unusual in the Coastal Plain area. It is molded on an end-cut auger machine, dried on hot floors, and burned in up-draft kilns with permanent side walls.

The plant of the Builders Supply Company is located on Middle Street, Chesterfield Heights. The clay is a light-colored sandy material averaging about 3.5 feet in thickness. There are only a few inches of soil over it, and the clay is free from stones or shells.

G. A. Stephens' brick yard is located on the Princess Anne road near Godfrey Avenue. It is also working surface clay, which, however, is somewhat different in its appearance from that at the preceding plant. The clay which immediately underlies the soil is a bluish-black, very stiff red-burning clay.

C. H. Phillips and Brothers operate a yard at Hampton, near Newport News, and a reddish, sandy, surface clay is used, for making common soft-mud brick.

At Morrison, 1 mile north of the station, is the yard of the Booker Brick Company, whose product goes mostly to Norfolk. This is a shallow Pleistocene deposit, 3 to 4 feet in depth and underlain by sand. The material is red-burning and used only for the manufacture of common brick.

The Suffolk Area.

Four brick yards were visited at this locality, namely, those of the Standard Brick Company, Horrell and Company, Suffolk Clay Company, and West End Company.

The Standard Brick Company's yard is located about one mile and a half south of Suffolk along the Southern Railway. The surrounding region is underlain by a deposit of sand, often of coarse grain and variable thickness. Some of it might serve for molding sand, and much of it no doubt would answer for the manufacture of sand-lime brick. At the pit of the Standard Brick Company, some stripping is necessary before the clay is reached. The bed has a depth of about 6 feet, the lower two or three feet being a dark bluish-gray and the upper half discolored by weathering. The lower clay gives a harder brick but has a higher shrinkage than the top clay.

The yards of the Suffolk Clay Company, and the West End Company, are located west of Suffolk and on adjoining properties; in fact, the clay deposits worked at the two are probably continuous at the yard of the West End Company. The clay deposit varies from 5 to 15 feet in thickness with very little overburden. It is underlain by a bed of black sand, which in places is quite clayey, but is not dug with the brick clay. The clay has been traced horizontally for at least 200 yards, and contains few stones. No sample of this was tested. The clay is worked up in a stiff-mud machine, and dried in twenty-four hours in steam-heated tunnels.

At the bank of the Suffolk Clay Company, the section shows:

	Feet
Top soil	1
Yellow clay	3
Blue clay, lower foot sandy	9
Limonite sand	1
Sand	8
Blue marl	20

For brick making the run of the bank, including the sand layer, is used. The blue clay is not safe to use alone by any process of wet-molding, but it gives a harder, denser body. The properties of the brick mixture (No. 1345) and the blue clay (No. 1344) are given in the table, opposite page 225.

The following table gives the statistics of clay products in the Virginia Coastal Plain from 1905 to 1909 inclusive, and is of interest to those who desire to know something of the growth of the industry in the eastern part of the State.

Clay products in Virginia Coastal Plain from 1905 to 1909, inclusive.[a]

Year.	No. of Producers.	No. of Counties Producing.	Value.
1905	43	16[a]	$1,485,227
1906	40	14[b]	1,424,220
1907	39	16[c]	1,098,998
1908	39	15[d]	1,199,533
1909	42	17[e]	1,473,728

[a] Includes Alexandria, Charles City, Chesterfield, Elizabeth City, Fairfax, Greenesville, Henrico, James City, King George, Lancaster, Nansemond, Norfolk, Prince George, Princess Anne, Spottsylvania, and Warwick counties.
[b] Includes Isle of Wight County, and the counties under (*a*) except Greenesville, Princess Anne, and Spottsylvania.
[c] Includes Isle of Wight and Sussex counties, and the counties under (*a*) except King George, and Spottsylvania.
[d] Includes Caroline, Isle of Wight, and Sussex counties, and the counties under (*a*) except Elizabeth City, Greenesville, and King George.
[e] Includes Isle of Wight and Sussex counties, and the counties under (*a*) except Caroline and Elizabeth City.

Of the 17 counties producing in 1909, Alexandria, Henrico, Chesterfield, and Nansemond, in the order named, were the largest producers. During 1909, there were 9 producers in Alexandria County, 7 in Henrico, 6 in

[a]Furnished by the courtesy of the Division of Mineral Resources, U. S. Geol. Survey.

Chesterfield, and 5 in Nansemond. The total production of these 4 counties amounted to $1,219,090 or 82.72 per cent. of the total production for the entire Coastal Plain region.

SAND AND GRAVEL.

Sand and gravel are found in almost every one of the Coastal Plain formations. The sands of the Virginia Coastal Plain region are employed as building sand, molding sand, engine sand, and in the manufacture of sand-lime brick. Gravel and sand are also used for road-building.

Sand.—Sand, both coarse and fine, is found in almost every one of the Coastal Plain formations. At times the sand consists of pure quartz grains, but at other times is mixed with more or less clay or gravel and occasionally, particularly in the Potomac deposits, arkose forms the matrix for the sand grains. These are sometimes covered with a ferruginous coating which tends to bind the grains together. Ferruginous sands pack together much better than the pure quartz sands and hence afford much finer roads where they form the surface materials. The very sandy roads common in the eastern part of the State are caused by the absence of binding material to hold the solid grains together.

The better grades of sand have been locally used in great quantities for building purposes. Some of the sands are probably pure enough to be utilized as glass sands although none have been employed for that purpose hitherto. In New Jersey some of the Miocene quartz sands have been used in the manufacture of glass, and doubtless the same formations in Virginia contain equally desirable materials for glass-making.

Molding sand has been obtained from several pits along Gillis Creek in the southeastern part of Richmond, and is of very good quality. Most of it is used in Richmond although some has been shipped elsewhere. This sand belongs to the Aquia formation and contains considerable glauconite, a constituent of all the Eocene sands. The deposit is of a pepper and salt color with certain portions stained brown by the iron oxide produced in the decomposition of the glauconite. There are at times small pebbles in the sand while certain beds contain casts of fossils. Sand with apparently similar characteristics is found throughout the Aquia formation, so that it is probable that much material suitable for molding purposes can be obtained from this formation throughout the Virginia Coastal Plain region. In Maryland some of the slightly arkosic sands from the Potomac deposits have also been used as molding sands which suggests the probable occurrence of equally desirable sands in the same formation in Virginia.

During his investigations of the Virginia Coastal Plain clays in the summer of 1905, Dr. Heinrich Ries studied the molding sands in the vicinity of Richmond, Petersburg, and Fredericksburg. The samples of these sands collected by Ries were analyzed by Messrs. Eoff and Gibboney, with the results shown in the table which follows below.

Analyses of molding sands from the Virginia Coastal Plain region.

Constituents	I Per cent	II Per cent	III Per cent	IV Per cent	V Per cent	VI Per cent
Silica (SiO_2)	81.59	82.08	66.12	82.32	70.24	70.40
Alumina (Al_2O_3)	6.46	7.12	16.54	7.80	16.62	3.80
Iron oxide (Fe_2O_3)	4.94	4.63	4.46	3.98	3.94	14.94
Lime (CaO)	0.14	0.36	0.40	0.54	0.08	0.12
Magnesia (MgO)	0.22	0.35	0.22	0.41	0.09	0.15
Potash (K_2O)	1.19	1.28	2.67	1.64	1.41	1.95
Soda (Na_2O)	0.59	0.41	0.35	0.80	0.74	0.41
Titanic oxide (TiO_2)	1.90	0.30	0.14	0.22	0.46	0.70
Water (H_2O)	1.63	1.66	4.90	0.19	4.16	4.08
Water (moisture)	1.46	1.52	4.15	0.14	2.42	3.77
Total	100.12	99.71	99.95	98.04	100.16	100.32

Constituents	VII Per cent	VIII Per cent	IX Per cent	X Per cent	XI Per cent
Silica (SiO_2)	84.40	93.92	85.04	86.24	89.39
Alumina (Al_2O_3)	7.56	3.22	5.90	6.32	5.94
Iron oxide (Fe_2O_3)	2.52	1.08	3.18	2.44	1.22
Lime (CaO)	0.06	0.24	0.06	0.34	0.32
Magnesia (MgO)	0.21	0.08	0.14	0.10	0.09
Potash (K_2O)	1.29	0.45	1.65	1.38	2.10
Soda (Na_2O)	0.65	0.23	0.83	1.13	0.53
Titanic oxide (TiO_2)	0.44	0.32	0.78	0.02	0.18
Water (H_2O)	1.99	0.48	1.57	2.94	0.54
Water (moisture)	1.76	0.18	1.11	1.29	0.19
Total	100.88	100.20	100.26	102.20	100.50

I. Redford sand from foundry, Manchester, Virginia.
II. Redford yellow sand collected at pit, Manchester, Virginia.
III. Coarse sand, Harbaugh pit, Richmond, Virginia.
IV. Used molding sand, Redford pit Manchester, Virginia.
V. Sand from near Petersburg, Virginia.
VI. Blandford pit, Petersburg, Virginia.
VII. Armstrong pit, Petersburg, Virginia.
VIII. Sand from near Standard Brick Company, south of Suffolk, Virginia.
IX. Griffith's pit, Fredericksburg, Virginia.
X. Curlis pit, southeast of Lanexa, New Kent County, Virginia.
XI. One mile south of Layton, Essex County, Virginia.

The following physical tests made by Ries on the samples of sand from Virginia further serve to show their general character:

Locality	20	40	60	80	100	100X	Clay
Redford yellow sand collected at pit in Manchester	1.51	1.26	1.27	0.56	6.27	71.69	16.52
Coarse sand, Harbaugh pit, Richmond	42.48	12.90	6.16	0.85	1.70	8.58	26.44
Nsed molding sand, Redford pit, Richmond	5.34	14.73	10.41	1.28	14.61	59 37	3.52
Sand from near Petersburg..........	0.73	2.34	8.76	2.21	12.25	14.79	30.54
Blandford pit, Petersburg............	3.03	1.41	0.97	0.40	2.61	48.32	41.87
Armstrong pit, Petersburg	0.09	0.41	2.21	2.67	17.37	53.20	19.02
Sand from near Standard Brick Company, south of Suffolk.............	0.12	0.29	13.00	6.56	38.02	35.18	6.03
Griffith's pit, Fredericksburg	0.19	0.19	0.39	0.19	0.98	81.92	15.97
Curlis pit, southeast of Lanexa	.....	0.01	0.08	0.07	1.11	86.77	19.57
One mile south of Layton	6.68	28.13	51.66	3.18	3.75	2.63	2.16

Along the tide-water streams on the sandy beaches may be seen thin layers of heavy black sands, composed largely, if not entirely, of grains of magnetite. These beaches are sometimes covered to a depth of several inches with almost pure sands of this character, although usually the fine sandy beaches contain layers of black sands interbedded with fine yellow sands. In some places along the lower Rappahannock River it would be impossible to obtain sands of this character in considerable quantities. It is doubtful whether the sands will ever prove valuable as an iron ore but it is possible that other minerals of greater value may be present with the magnetite. Investigations recently carried on by the United States Geological Survey on the black sands of the Pacific Coast have revealed the presence of magnetite, ilmenite, chromite, zircon, and monazite, all of which have a commercial value in the arts. In some places such sands contain gold and platinum. Although the black magnetite sands of Virginia are probably of little value in comparison with the much more abundant deposits on the Pacific slope, it is desirable that their composition be determined.

Gravel.—The Lafayette, Sunderland, Wicomico, and Talbot formations furnish the principal gravel deposits of the Coastal Plain, although the Patuxent and Patapsco formations also contain locally considerable beds of gravel. The last two formations have a very limited outcrop in Virginia so that their economic importance as a source of gravel is not great. The other four formations, however, contain an abundance of gravel suitable for road-making, and their wide distribution renders them of particular value throughout the greater portion of the region. One or another of these formations is present almost everywhere in the Coastal Plain except on the steeper slopes, and even in such places the talus consists largely of Pleisto-

cene or Lafayette débris. Generally a gravel band is found at the base of each of these formations, covered by a surface loam cap in which are distributed scattered pebbles or pebble lenses.

The Lafayette, in its most western limits, is almost entirely composed of the clay residuum of the crystalline rocks, and the Pleistocene deposits in the extreme eastern portion of the State are often composed almost entirely of fine sands but elsewhere these formations contain much gravel. The gravel is more abundant in proximity to the larger streams and decreases in amount and in size of the pebbles over the broader divides, yet removal of the upper clay loams at some distance from the main streams will usually reveal the presence of a gravel layer.

Gravel pits are numerous although much less use has been made of the deposits for road purposes than one would expect when it is everywhere recognized that the heavy sandy roads have been serious drawbacks to the development of the country in so many portions of the Virginia Coastal Plain. The gravel is of very unequal value for road-building purposes, depending primarily on the matrix in which the gravel occurs. Pure quartz gravel in a matrix of loose sand will not pack of itself and is of little value if spread on sandy roads. If spread over a clay road, however, it will become mixed with the clay and eventually form a firm road bed. In some places the gravel occurs in a clay or ferruginous sand matrix and is then splendidly adapted for road-building purposes. By making several applications of such gravels the worst highways can eventually be converted into firm roads both in dry and wet weather.

The table below shows the details of the sand and gravel industry of the Virginia Coastal Plain, and the comparative quantities and values in 1908 and 1909.

Production of Sand and Gravel in Virginia Coastal Plain, 1908 *and* 1909, *by uses, in short tons.*

	1908		1909	
Sand—	*Quantity*	*Value*	*Quantity*	*Value*
Glass	......	.....	....	....
Molding	41,900	$ 20,925	15,489	$ 12,605
Building	103,936	46,096	340,318	107,749
Fire	......	.....	....	....
Engine	......	.....	1,526	220
Furnace	2,960	2,554	1,379	1,881
Other	4,712	760	43,631	6,349
Gravel	234,894	24,154	319,487	69,631
Total	388,402	$94,489	721,830	$198,435

These figures do not represent the total production of sand and gravel in the Virginia Coastal Plain, as large quantities are produced and utilized

each year in the manufacture of brick, and in railway, highway, and sidewalk construction, etc., of which no record of the quantity used is kept and no returns are made to the office of the State Survey. Much the largest proportion of sand used in the State, for which returns are made, is for building and molding.

DIATOMACEOUS EARTH.

Diatomaceous earth, known in the trade under the name of "silica," "infusorial earth," or "tripoli," is composed of the minute shells or tests of microscopic plants known as diatoms, and is widely distributed in the Calvert formation. It was first reported from the vicinity of Richmond, Virginia, and for that reason received the name of "Richmond earth," under which term it is sometimes referred to in the literature. Because of its occurrence at Bermuda Hundred on the James River, it has been called "Bermuda earth."

The first bed of diatomaceous earth of any extent discovered in this country was in the Richmond area. It is known as the Richmond bed, which extends from Herring Bay on the Chesapeake, Maryland, to Petersburg, Virginia, and probably beyond. It is not less than 30 feet in thickness in places, though very impure at times, grading frequently into layers of clay. It is of Miocene (Calvert) age, light brown and red to almost pure white in color, and is exposed along the numerous streams close to their crossings from the crystalline rocks on to the sediments of the Coastal Plain.

Specimens of the diatomaceous earth collected from various points in the Virginia Coastal Plain region gave the following results on analysis:

Analyses of Virginia Diatomaceous Earth.

Constituents	I[a]	II[a]	III[b]	IV[b]	V[b]	VI[b]
Silica, amorphous	65.83	51.67	63.17	70.42	78.82	82.85
Silica, crystalline	14.65	23.56				
Alumina	4.17	10.25	19.30	15.15	9.24	9.76
Ferric oxide	2.34	2.79	6.32	5.17	5.42	2.34
Lime	trace	0.27	0.06	0.14	0.04	0.35
Magnesia	0.71	0.69	0.69	0.79	0.12	1.06
Titanic oxide	0.40	0.64	0.88	0.44	0.33	1.09
Soda	....	....	0.69	0.39	0.81	0.99
Potash	....	....	2.45	2.24	1.51	1.07
Ignition	11.63	10.18	6.39	5.21	3.66	3.40
Total	99.73	100.05	99.95	99.95	99.95	99.91

[a]Smither, F. W. Analyses of Infusorial Earth. Amer. Chem. Jour., 1897, Vol. XIX, pp. 235-236.

[b]Ries, Heinrich. A Preliminary Report on a Part of the Clays of Virginia. Bull. No. II, Geological Series, Virginia Department of Agriculture and Immigration and Virginia Polytechnic Institute, 1906, p. 143.

I. Diatomaceous earth from the northern bank of the Rappahannock River at Greenlaw's Wharf, King George County. F. W. Smither, analyst.

II. Diatomaceous earth from President's Hill, Richmond, Virginia. F. W. Smither, analyst.

III. Diatomaceous earth from 7th Street, near Richmond Locomotive Works, Richmond, Virginia. Eoff and Gibboney, analysts.

IV. Diatomaceous earth from same locality as III. Eoff and Gibboney, analysts.

V. Diatomaceous earth from the Rappahannock River south of Layton. Eoff and Gibboney, analysts.

VI. Diatomaceous earth from Wilmont on the Rappahannock River. Eoff and Gibboney, analysts.

It will be seen from examination of these analyses that the earths show much variation in their chemical composition. I, II, and III show low silica, and the first two are described as being unusually pure, as indicated by microscopic study. IV, V, and VI are quite siliceous and one of them highly so. These are shown from microscopic study to be less pure than I and II, and III and V are very impure.

The diatomaceous deposits around Richmond have long been known, and are referred to in many publications. The beds outcrop in great thickness in the embankments along the tracks at the Richmond Locomotive Works, and along the sides of the valley to the west. In general character the earth is a silty porous clay, which breaks out in irregular lumps. In places it is traversed by vertical fissures which are filled with limonite. Analyses II, III, and IV in the table above are of diatomaceous earth occurring around Richmond.

There are long exposures of diatomaceous earth along the Rappahannock River, especially in the vicinity of Layton and Wilmont. The diatomaceous earth beds have a thickness of about 50 feet and stand out in bold almost vertical cliffs, which when viewed at a distance present an appearance almost as white as chalk. These cliffs stand out prominently in the sunlight and can be seen for a long distance. This earth is apparently purer and lighter than much of that around Richmond, and like the latter it passes in places into clay. Analyses I, V, and VI in the table above are of diatomaceous earth occurring at Greenlaw's Wharf, King George County, and near Layton and Wilmont, Essex County, on the Rappahannock River. Other good exposures of the earth are at Carter's Wharf on the Rappahannock River, and along Shockoe Creek in the eastern part of Richmond with an indicated thickness of about 20 feet.

On account of its porosity and compactness diatomaceous earth is used in water filters and as an absorbent of nitroglycerine in the manufacture of dynamite. It is reduced readily to a fine powder, the hardness of the individual particles and their sharp edges making it an excellent base for polishing compounds. Its low heat conductivity makes it a valuable ingredient in the manufacture of packing for steam boilers and pipes, and in the construction of fire-proof safes. It has been frequently utilized for the latter purpose. It has also been suggested that it might be used in certain branches of pottery manufacture, which require on the part of the materials both refractoriness and an absence of color when burned.

In 1905, samples of diatomaceous earth were collected around Richmond and the Rappahannock River, and tested by Dr. Heinrich Ries. The results of the chemical analyses are given in the table above, and those of the physical tests on page 246.

Physical Tests made of Virginia Diatomaceous Earth.

Laboratory Number.	III (1322)	IV (1323)	V (1358)	VI (1363)
Color, moist	Brown buff	Buff	Light yellow	White
Water required	31.6	34.6	23.1	62.4
Slaking	Fast	Fast	Fast	Fast
Plasticity	Lean	Lean	Low	Low
Grit	Some	Some	Little	Some
Air shrinkage	13	14	10.3	3.6
Average tensile strength	.....	.....	29.4	34.4
Cone 010				
Fire shrinkage	0.6	0.6	0.6	1.3
Color	Light red	Light red	Light red	Yellowish
Absorption	14.62	14.9	21.73	50.96
Cone 05				
Fire shrinkage	0.6	2.3	0.6	1.6
Color	Light	Light	Light	Light pink
Absorption	13.6	10.9	20.70	48.4
Cone 03				
Fire shrinkage	2	3.3	2.3	1
Color	Light red	Light red	Light red	Pink
Absorption	12.42	9.0	15.88	44.70
Cone 1				
Fire shrinkage	3	5	5.6	4.6
Color	Light brown	Medium red	Pink	Pink cream
Absorption	9.1	4.16	11.3	41.4
Cone 3				
Fire shrinkage	3.3	6	5.6	4.6
Color	Red brown	Medium red	Red gray	Yellow
Absorption	6.9	2.30	9.5	40.9
Cone 5				
Fire shrinkage	5	6	6	5.3
Color	Red gray	Red gray	Light brown	Yellow
Absorption	5.06	1.70	5.4	38.3
Cone 8				
Fire shrinkage	2	5.5	6.3	5.6
Color	Brown	Red gray	Light brown	Yellow brown
Absorption	2.04	1.08	2.57	32.32

III. (No. 1322). Weathered diatomaceous earth from 7th Street, near Richmond Locomotive Works, Richmond. This, after burning, closely resembles the diatomaceous earth near Layton along the Rappahannock River. It seems to be vitrified at cone 5, and at cone 8 is viscous.

IV. (No. 1323). This sample was collected from the same locality as No. 1322, but at greater depth below the surface. It is quite impure, and shows a high air shrinkage. It burns red and becomes steel-hard at cone 05. It is vitrified at cone 5, and nearly viscous at cone 8.

V. (No. 1358). Diatomaceous earth along the Rappahannock River south of Layton. This burns fairly dense at the higher cones, and gives a clean color, but is quite porous at the lower cones.

VI. (No. 1363). Diatomaceous earth from Wilmont. This burns to a very porous body as is indicated by the absorption figures. It has a low air and fire shrinkage.

Though occurring in the Coastal Plain region in great abundance, the deposits of diatomaceous earth are worked at present only to a very limited extent. At Wilmont some of this material is mixed with Pleistocene clay and used in the manufacture of brick. A few years ago it was quarried and shipped from a point on the Rappahannock River a short distance below Wilmont but the plant has now been abandoned. According to the United States Census office, the output of diatomaceous earth in Virginia in 1902 was limited to the production of two concerns. There has been no reported production of diatomaceous earth in Virginia for several years.

GREENSAND MARL.

The Eocene and locally the Miocene deposits of Virginia contain considerable glauconite, a dark green mineral which is essentially a hydrous silicate of iron and potash. The glauconite occurs in the form of small grains, varying in amount from very nearly pure beds of that substance to deposits in which the arenaceous and argillaceous elements predominate. At certain places the shells of organisms are found commingled with the glauconitic materials in such numbers as largely to make up the beds, producing what is known as a greensand marl. Such a marl contains two of the most important constituents to plant growth, potash and lime, while most analyses show a small percentage of phosphate of lime even more beneficial as a plant food. It is for these reasons that the greensand or glauconitic marls have long been known to be of value as natural fertilizers. The marl improves both the chemical and physical condition of the soil. It is very lasting in its results, the effects being noticeable for many years, but its bulkiness will probably always prevent it being extensively used in its

natural condition except locally. From 60 to 100 bushels per acre should be used on sandy soils and from 160 to 200 bushels on clay soils.

Greensand deposits of Upper Cretaceous age have been worked for more than 100 years in New Jersey and almost invariably the users report increased soil fertility. Similar deposits of Tertiary age have been worked in Delaware, Maryland, and Virginia but to a less extent. To obtain the best results the marl should be dug and allowed to weather for a few months in order to permit all the firmer masses to disintegrate, after which it is spread over the surface of the ground in a thin layer.

Besides serving as a natural fertilizer, greensand marl is now frequently used as a base in the manufacture of artificial fertilizers. For this purpose the greensand is dried, pulverized and then shipped to the fertilizer plants. Most of the greensand marl now dug in New Jersey and Virginia is being used in this way.

The distribution of greensand marl in Virginia is almost coextensive with the distribution of the Aquia and Nanjemoy formations, as both of these contain a great deal of glauconitic sand. The region along the Pamunkey River is underlain by valuable deposits and more has been dug there than at any other locality in the State. Similar material outcrops along the Potomac and the Rappahannock rivers and their tributaries in Stafford, King George, and Caroline counties and along the James River and its tributaries in Henrico, Charles City, and Prince George counties. Extensive beds of greensand marl occur in portions of James City, York, Hanover, Chesterfield, Prince William, and Spottsylvania counties. The beds vary greatly in depth and in the amount of potash and phosphoric acid contained. Potash varies according to the proportion of the mineral glauconite present, ranging usually from one per cent in the very impure greensands to 8 and 10 per cent in the purer greensands. Shells are usually present in the deposits and supply lime in addition to potash and phosphoric acid.

Greensand marls have been dug at a number of places on the James and Pamunkey rivers. The most important place for the production of marl within recent years is on the James River in Prince George County a few miles below City Point. The marl was there dug, dried and shipped. Some Miocene shell marl was also ground up with the greensand marl.

The following analyses, made of greensand marls collected from Hanover, Suffolk, and Prince George counties, Virginia, and Aquia Creek, Stafford County, Virginia, serve to show their composition:

Analyses of Virginia Greensand Marl.

	Major Winston[1] Hanover County		Aquia Creek[2] Stafford County	Waverly[3] Sussex County	City Point[3] Prince George County	
	Per cent	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
				Insol.		
SiO_2 combined	47.45	43.34	.....	.....	.....	.....
SiO_2 uncombined	2.76	8.22	21.58	45.20	61.15	56.03
Al_2O_3	7.33	6.62	7.70	.....	.....	.....
Fe_2O_3	12.03	15.16	.....	.....	.....	.....
FeO	9.43	8.33	.....	.....	.....	.....
MgO	2.90	0.95	1.05	5.22	2.19	0.37
CaO	0.57	0.62	36.78	24.38	1.36	1.52
K_2O	5.75	4.15	0.37	4.73	3.85	3.15
Na_2O	0.42	1.84	0.59	.....	.....	.....
P_2O_5	.....	.....	0.09	1.80	0.47	0.05
H_2O	9.85	10.32	0.76 (at 110°)	.....	.....	.....
CO_2	.....	.....	29.79	.....	.....	.....
Volatile at red heat less CO_2	.....	.....	0.21	.....	.....	.....
Total	98.49	99.55	98.92			
Siliceous matter			25.36			

[1]Corse, M. B. and Baskerville, Chas. Analyses of Glauconite from Hanover County, Virginia. Amer. Chem. Jour., 1892, Vol. XIV, p. 627.

[2]Analysis by Peter Fireman of Columbia University.

[3]Ellett, W. B., and Eskridge, A. T. Virginia Experiment Station Bulletin.

CALCAREOUS (SHELL) MARL.

The various Miocene formations of Virginia, especially the Yorktown, contain extensive deposits of molluscan shells, and frequent fish and mammalian bones. The marl beds usually attain considerable thickness as well as lateral extent, and the percentage of lime in them is very high. Analyses of the marls generally show a small amount of potash and phosphoric acid. The percentage of lime in the beds depends largely upon the amount of sand and clay present, forming the matrix of the beds, as the shells are composed almost entirely of calcium carbonate. Some of the marls contain as much as 97 per cent of calcareous matter. The bones yield most of the potash and phosphatic material present, some of the Miocene bones containing as much as 30 per cent of phosphoric acid. The calcareous or shell marls owe their principal value, however, to the lime content.

The large areal extent and high lime content of the Virginia Miocene shell marl beds render them of great commercial value for use (a) in

agriculture, and (b) in the manufacture of Portland cement. These two principal uses of the Virginia shell marls are discussed separately in the order named.

Use in Agriculture.—As a fertilizer lime has wide application on acid soils or those deficient in lime. Lime has been used to some extent as a fertilizer for many years, but it is only within recent years that considerable scientific attention has been directed to its use. Many of the state agricultural experiment stations have investigated the use of lime as a fertilizer.

The effect of lime upon soils is three-fold: (1) It produces important chemical changes; (2) it changes the physical properties of soils which are deficient in calcium; and (3) it serves as a plant food as it is an essential constituent of many plants.

Chemically lime tends to break up many refractory minerals whose elements reunite to form other compounds which are soluble and can serve as plant foods. It replaces potash in certain of the silicates, liberating that element in such form that it may be used directly by the plant. If the soil contains much humus or vegetable matter the lime will promote its decomposition, resulting in liberating nitrogen in the form of ammonia which is a valuable plant food. Heavy and continuous liming may be carried to such an excess that the plant food will be liberated more rapidly than the plants can make use of it. Because of its alkaline nature, one of the most important functions performed by lime when applied to acid soils is the neutralizing of acidity.

Physically lime ameliorates the texture of the soil. Clay soils which have a tendency to cake upon drying are rendered more open and porous in texture by liming, while loose sandy soils may be rendered more compact and retentive of moisture by liming.

Professor H. J. Patterson[1] states that "most cultivated soils possess a slightly acid reaction. This is generally due to the decomposition of the remains of plants in the soil forming organic acids. On wet soils this condition is more noticeable than on dry soils. The sour humus and organic acids are not only unfavorable to the growth of nitrifying ferments and the root tubercles of leguminous plants, but also are likely to dissolve iron and other compounds which are poisonous to crops. Water-culture experiments have shown that slightly acid solutions are favorable to the growth of plants, and while most soils possess this character to slight

[1]Maryland Agriculture Experiment Station Bulletin 66, p. 97.

degree, yet any excess of soluble acid in the soil would be highly detrimental. While most of our cultivated crops seem to need a slight acidity, it is probable that they have the ability to create this condition to a sufficient degree through the medium of the solutions sent out by their roots. This being the case, it would seem that the aim should be to keep soils in a neutral or slightly alkaline condition, so as to favor the growth of root tubercles of the legumens and the desirable soil ferments. Liming is excellent for correcting any excess of acidity, and is probably the most effective and economical substance for bringing about these other desirable conditions." It is a well-recognized fact that sheep-sorrel thrives in an acid soil where grass and grain will scarcely grow at all. In such places the application of lime or marl destroys the soil acidity with the resultant destruction of the sheep-sorrel and renders possible the growth of profitable crops.

"The many chemical changes brought about by the action of lime on soils result in producing physical changes which give soils new mechanical characteristics. Lime has the power of changing the physical properties of a clay soil and making it more friable and easily cultivated, and putting it in a condition so that water may pass more freely through it. This will make it less susceptible to extremes of dry and wet weather, and make it a good home for the roots of the plants. The action of lime on sandy soils may be said to be the reverse of that on clay soils; that is it has a cementing action, making such soils stick together in such a condition that they will hold more water and not dry out so rapidly."

Shell marl is somewhat less valuable than commercial lime, because of its slower action, yet all the advantages claimed for lime as a fertilizer may be equally well claimed for the natural marl. In many places throughout Tidewater Virginia shell marl has been extensively used and, except when put on in too large quantities, has materially increased soil fertility and proved a valuable stimulus to plant growth. In many places, however, since the Civil War very little marl has been used, notwithstanding the fact that much excellent marl is locally available. In some places the fossil shells have been burned for lime, which is spread over the surface. In this form the lime becomes effective almost immediately, which is often very desirable. Where the shells are very well preserved and compact, the action of the natural shell marl is very slow, some shells remaining in the soils for a great many years almost unchanged.

Generally the marls made up of the shells of *Ostrea, Pecten, Venus*. and *Crassatellites* are poor fertilizers on account of the slowness with which

they decompose, while the gastropod shell marls are much better on account of their more friable texture and more rapid decomposition. The *Chama* marls are especially desirable. Shell marl has been dug in past years at numerous places in the Virginia Coastal Plain, and used extensively on the land, but little has been dug in recent years.

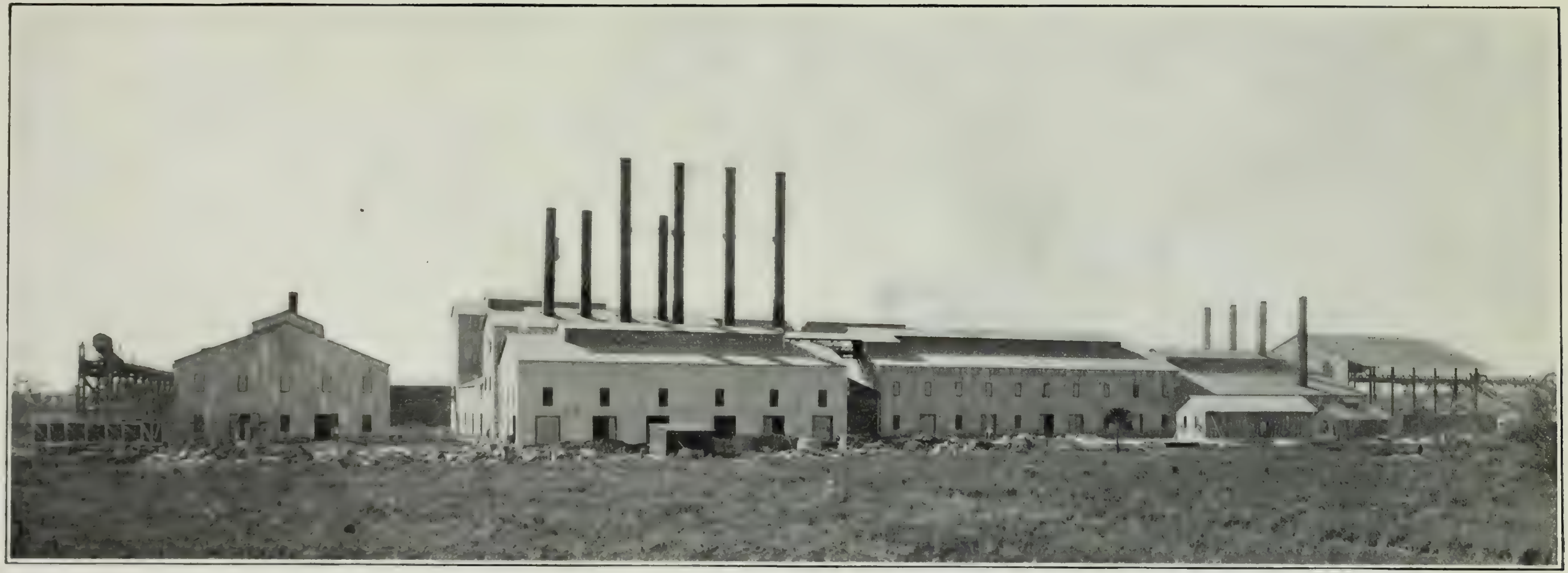
Use in Portland cement manufacture.—Only within the past several years has serious attention been drawn to the shell (calcareous) marls of the Coastal Plain as raw material for use in mixing in the manufacture of Portland cement. Investigations conducted by the State Geological Survey show that extensive deposits of shell marls of good grade and suitable for the making of Portland cement occur in many places in the Virginia Coastal Plain. The most favorable deposits are of Miocene age, the areal distribution of which is shown on the accompanying map, Plate I. Of the Miocene formations, the Yorktown is one of the most fossiliferous represented in the series of Atlantic Coastal sediments. It has a thickness in Virginia of approximately 125 feet and contains a very rich and varied fauna. The formation outcrops in Gloucester, James City, York, Warwick, Isle of Wight, and Nansemond counties.

In their natural state, some of the marls contain too large a percentage of sand to be used directly in cement making, but must be treated by a simple process before mixing in order to reduce the sand content, which proportionately increases the calcareous matter. Associated with the marls in many places are beds of clay of sufficient thickness and quality as to render them suitable to mix with the calcareous marl for Portland cement manufacture.

Recently, three plants of large capacity have been granted charters for the manufacture of Portland cement in the Coastal Plain (Tidewater) region of Virginia. These are the Norfolk Portland Cement Corporation's plant located near Norfolk, the Jamestown Portland Cement Corporation's plant to be located at Yorktown, and the Colonial Portland Cement Corporation's plant to be located at the Grove, 7 miles east of Williamsburg. Of these, the plant of the Norfolk Portland Cement Corporation has been completed and is producing. The raw materials to be used by these plants in the manufacture of Portland cement are the Miocene marls and clays of the immediate area.

The Norfolk Portland Cement Corporation's plant[a] located on the southern branch of the Elizabeth River opposite the United States Navy-

[a]Summarized from an article by Wm. H. Stone in the Manufacturers Record, Oct. 13, 1910, pp. 49-50.



General view of Norfolk Portland Cement Corporation's plant, opposite U. S. Navy Yard, near Norfolk. Storage bin adjoining wharf shown on left; coal house on right; main portion of plant in center. (Courtesy of Wm. H. Stone, Manufacturers Record.)

NORFOLK PORTLAND CEMENT CORPORATION'S PLANT.

yard at Norfolk, is the first plant built in the South to manufacture Portland cement from shell marl as the principal calcareous material used instead of the hard rock-limestone (Plate XIX, figs. 1 and 2). The marl deposits are located on branches of the James River near Smithfield and Chuckatuck, about 25 miles from the plant. Reported analyses of the marls and clays used as a mix in the making of cement by this plant are as follows:

Analyses of marl and clay from the Norfolk Portland Cement Corporation's property, near Norfolk, Va.

Constituents	Marl	Clay
Silica (SiO_2)	7.24	62.99
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	4.92	23.45
Lime (CaO)	47.67	4.82
Magnesia (MgO)	trace	trace

It is reported that previous to building the plant at Norfolk the material from the Virginia marl deposits was shipped during the past 10 years to the American Cement Company at Egypt, Penna., for the manufacture of Portland cement. The cement made at Norfolk is marketed under the American Cement Company's established brand "Giant," a guarantee that the new cement made from the Virginia Coastal Plain marls and clays is in all respects the equal of that upon which the Pennsylvania company has made its reputation.

The company has built a line of railway extending from the large marl and clay deposits which it controls, to a pier constructed for loading the raw materials on barges of 500 tons capacity each, whence they are conveyed to the plant at Norfolk. Upon arrival at the plant the raw materials are delivered from the barges into bins, by buckets having a capacity of 100 tons per hour, operated by two hoisting engines. The bin for marl has a capacity of 500 tons and the one for clay a capacity of 100 tons.

There are four kilns, each of 500 barrels capacity, with provisions for a fifth. After burning to clinker and crushed, the finished product is carried by screw conveyors to the stock houses of which there are two; one used for storing cement shipped by rail and the other on the loading wharf for storing cement to be shipped by water. The plant, covering four and one-half acres, is a large and commodious one, entirely modern and is fully equipped with the necessary machinery, etc. (Plate XVIII).

The Jamestown Portland Cement Corporation's property is located at Yorktown on the south side of York River. The marl beds are exposed in bluffs ranging from a few feet up to 40 and 50 feet along the York River, and in ravines which extend back from the river, the principal one of which is Wormley Creek (Plate XIX, figure 1). The marls are of of Miocene (Yorktown) age. The Yorktown formation in Virginia has a thickness of approximately 125 feet, and is described in detail on pages 158 to 166. A carefully measured section is given on page 161, to which the reader is referred. The maximum working thickness of the formation for cement manufacture at any one place in the vicinity of Yorktown, will probably not exceed 30 feet above stream level. Its general dip varies from 5° to 25° northwest, with an average of about 15°.

Through the courtesy of Mr. H. E. Brown, Chief Engineer of the American Cement Engineering Company, I give below analyses of the marls occurring on the Jamestown Portland Cement Corporation's property. The first four analyses of the marl given below are reported to represent the entire face of the cliff shown in plate XIX, figure 1. Magnesia not exceeding 0.5 per cent is reported as occurring in all of the samples. These different layers are said to be found in practically all of the exposures and in most of the borings which have been made on the property.

Analyses of marls from the Jamestown Portland Cement Corporation's property, Yorktown, Va.

Constituents	I	II	III	IV	V	VI
Silica (SiO_2)	24.06	6.3	12.2	6.2	12.0	9.85
Alumina (Al_2O_3)	3.29	2.3	1.6	1.3	2.3	2.07
Ferric oxide (Fe_2O_3)	4.47	6.4	4.9	4.9	1.7	2.88
Calcium carbonate ($CaCO_3$)	76.71	84.5	80.5	87.1	83.8	78.20
Magnesium carbonate ($MgCO_3$)						0.28
Moisture						1.98

I. A low grade marl ranging from 4 to 6 feet thick at the bottom of the deposit.

II. Average sample of marl taken from a bed 6 to 10 feet thick immediately above I.

III. Average sample of marl taken from a bed 3 to 5 feet thick immediately above II.

IV. Upper bed of marl at top of deposit, overlain by sandy marls 2 to 4 feet thick and too siliceous for use in Portland cement manufacture.

V. Average sample of marl taken from a 10-foot exposure on Wormley Creek.

VI. Average of samples collected from a 15-foot thickness of marl exposed about 500 feet from the bluff shown in plate XIX, figure 1.

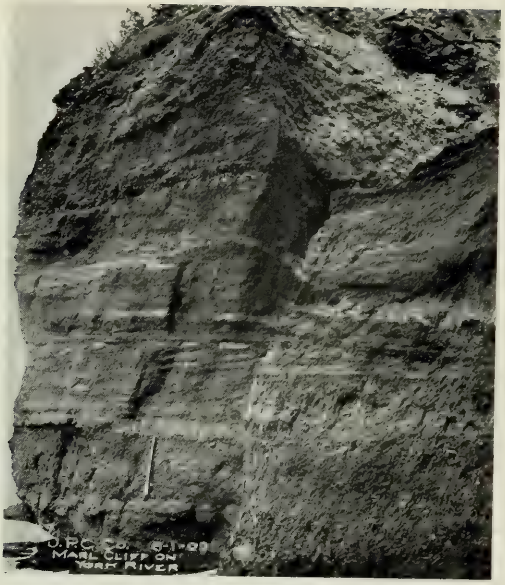


Fig. 1.—View of Miocene (Yorktown) marl beds at Yorktown. (Jamestown Portland Cement Corporation.)

Fig. 2.—View of Miocene (Yorktown) marl beds along north side of James River, south of Grove Station. (Colonial Portland Cement Corporation.)

MIOCENE (YORKTOWN) BEDS.

An analysis of the clays owned by the Jamestown Portland Cement Corporation, and which outcrop on the York River, is reported by Mr. Brown as follows:

Analysis of clay from the Jamestown Portland Cement Corporation's property, Yorktown, Va.

Silica (SiO_2)	65.94
Alumina (Al_2O_3)	22.50
Ferric oxide (Fe_2O_3)	6.60
Lime (CaO)	1.23
Magnesia (MgO)	1.50

A laboratory Portland cement plant owned by the American Cement Engineering Company was erected on the property of the Jamestown Portland Cement Corporation at Yorktown, for demonstrating purposes, in order to manufacture in the ordinary way, and according to mill methods, the marls and clays into standard Portland cement. The raw materials for this plant were secured from many different openings made in the marl deposits, and represent average samples such as will be secured in the operation of steam shovels when the marls are taken from bottom to top of the deposit.

Portland cement was successfully made from the marls occurring at Yorktown, which judging from the results of tests made in a number of the Government and private consulting testing laboratories, is in every respect the equal of many of the standard brands of Portland cement of wide reputation.

The Colonial Portland Cement Corporation's property is located at Grove, Virginia, on the James River and about half a mile from the Chesapeake & Ohio Railway. Two marl beds occur designated as "upper" and "lower," separated by an average thickness of 9 feet of clay, the top of which marks the bottom of the "upper" marl. The beds are exposed in a line of bluffs along the north side of James River, and in ravines which have cut down to a depth of from 20 to 30 feet. Plate XIX, figure 2, is a view of the marl beds exposed in the bluff along the river.

From measurements made in test pits and in natural exposures, the "upper" marl bed shows an average thickness of not less than 12 feet, and in many places it is 30 feet thick. The "lower" marl bed lies immediately below the clay bed and has been exposed to a depth of 10 feet, with the bottom of the bed not reached. The marl and clay beds are of Miocene age and belong to the Yorktown formation.

Numerous samples of the marl have been taken from all points over the property and carefully analyzed with the average results given in columns I and II below.

Analyses of marls from the Colonial Portland Cement Corporation's property, Grove, Va.

Constituents	I	II
Silica (SiO_2)	27.53	26.08
Alumina (Al_2O_3)	2.33	2.15
Ferric oxide (Fe_2O_3)	3.71	3.21
Calcium carbonate ($CaCO_3$)	63.67	65.80
Magnesia (MgO)	0.68	0.68[a]
Water (H_2O)	2.31	1.52[b]

[a]Average of 3 analyses.
[b]Average of 6 analyses.

By a simple process of crushing and screening the high silica in the marl is lowered and the calcium carbonate increased. Two different samples of the marl subjected to the above treatment gave the following results on analysis:

Analyses of marls from the Colonial Portland Cement Corporation's property, Grove, Va.

Constituents	I	II	III	IV
Silica (SiO_2)	5.69	5.81	52.13	53.14
Alumina (Al_2O_3)	1.06	1.18	10.00	8.63
Ferric oxide (Fe_2O_3)	0.86	0.62	6.46	6.16
Calcium carbonate ($CaCO_3$)	89.20	89.48	29.98	35.53
Magnesia (MgO)	.....	0.96	.....	1.14
Water (H_2O)	1.29	1.37	.....	4.55

I and II. Calcareous portion of two samples of marl obtained from crushing and screening.

III and IV. Clayey matter obtained from the two samples of marl as part of the same screening operation.

From a mixture of the two portions separated by screening (calcareous and clayey) a 30-pound sample was mixed and burned in a furnace, cooled, ground and tested by standard methods. The material responded well to all tests, exceeding in each case the standard requirements of Portland cement. It is believed therefore that the extensive marl beds

at Grove contain the necessary ingredients for the manufacture of Portland cement, and that by a simple process these ingredients can be combined in a suitable mixture.

The occurrence in the Virginia Coastal Plain of extensive beds of calcareous marls and clays suitable for cement making and which can be readily and cheaply dug, combined with the advantage of location of plants readily accessible to ocean steamers, the cheapness of labor, the mild climate which permits of working in the open air practically the entire year, and the proximity to the coal fields, unite to make this an unusually advantageous area for the manufacture of Portland cement.

MINERAL PAINT.

Brown hematite is frequently present in such large quantities in the Potomac and Lafayette clays as to form an impure ocher. Locally such deposits might be profitably worked, although little attempt has been made to develop them in Virginia. Limonite is present in certain beds in the Miocene in such amounts as to stain them a bright ocher yellow. Frequently it is found in small patches and almost pure but only in few places does it occur in large enough masses and sufficiently pure to be of much value.

Although ocher of more or less purity occurs in a number of places in the Virginia Coastal Plain region, attempts to mine it have been confined to the extreme eastern part of Chesterfield County, 4 miles southwest of Bermuda Hundred, on the Appomattox River. The material is an excellent grade of yellow ocher and was extensively mined for a period of years beginning in 1872, by the American Ocher Company. A high grade ocher was produced, the production amounting to 1,000 tons in 1880. It is said to have been considered by consumers preferable to the Rochelle product and to have materially lowered the market price of all foreign ochers. As a result of the competition, Rochelle ocher fell in price from 3¾ to 1¼ cents per pound. The mine was worked by tunnels extending into the hill from the bluffs of the river. The deposit was reported to have been about 7½ feet thick and is in the upper strata of the Calvert formation.

Three grades were made, all of the same grade but of different degrees of fineness, namely, "single washed," "double washed," and "extra floated." At the shipping point in Virginia, these grades have a value respectively

of $18, $21, and $27 per ton.[a] After grinding and washing the product, much of it was sold as yellow ocher, but it is said that greater profits were derived from the sale of red ocher which was obtained by burning the natural product (yellow ocher). Although the deposit does not seem to have been exhausted, the mine has not been in operation since about 1890.

IRON ORE.

Mining of iron ore in Virginia in 1609 by the Jamestown colonists was the first iron ore mined in the United States, of which there is any known record. The successful extraction of the metal from this ore led to the erection of the first iron works in the United States, which were located on Falling Creek in Chesterfield County, about seven miles south of Richmond, between the years 1619 and 1622. The works were destroyed in the Indian massacre of 1622 before they had been operated.

Much iron carbonate ore is present in the Potomac formations of Maryland and many iron furnaces were operated during Colonial days, but the Potomac in Virginia contains much less iron ore, and it is not positively known that any mines were ever worked in these formations in the State. There is a rumor that iron ore was formerly dug near Mt. Vernon.

Although nodules of iron carbonate and iron oxides pure enough to be economically valuable are found, it seems improbable that the Potomac formations of Virginia contain sufficiently large deposits to have much commercial value.

BUILDING STONES.

The building stones of the Coastal Plain are of little importance both on account of their limited occurrence and their inferior quality. In a region in which practically all the rocks are unconsolidated any indurated beds are pretty certain to be utilized locally for the foundations of buildings and for other purposes in which hard compact stones are not demanded. Indurated strata occur in almost every formation in the Coastal Plain of the State, and material from these beds has been employed widely for such local purposes.

The indurated sands (sandstone) of the Patuxent formation furnish the best building stone of the region and quarries have been opened up in

[a] Min. Res. of the United States, 1885.

these deposits in several places. This sandstone (Map, plate I), occurs in places along the eastern exposure of the crystalline rocks and extends for some distance below the head of tide. The rock is usually variable in texture, light gray or buff in color, and is composed chiefly of quartz and feldspar, the feldspar often decaying rapidly on exposure. The individual grains vary much in size, ranging from bird shot in size up to several inches in diameter.

In the early part of the last century much stone was quarried from the Patuxent formation near the mouth of Aquia Creek for use in the construction of public buildings in Washington. The Aquia Creek quarries were purchased by the United States Government in 1791 for the purpose of using the stone in the construction of public buildings in Washington. The stone from these quarries was used chiefly in the construction of many of the older public buildings in the above city, but the quarries were abandoned many years ago largely, it is said, because of the unfitness of the stone for exposed work. The old light house at Cape Henry was also constructed from the same kind of stone. On the Rappahannock River near Fredericksburg, and on the Appomattox River near Bermuda Hundred, similar material has been quarried for local uses. Some of this sandstone is very firmly indurated and forms a fairly good building stone that proves very durable, but in quarrying it much of the rock has to be wasted because of the pockets of loose sand which are frequently encountered.

The indurated marls of Eocene and Miocene age are widely distributed throughout the Coastal Plain and have furnished much material for the construction of foundations. These stones are not especially durable and they cannot be dressed neatly, hence they are used only for economical reasons in the absence of better local materials.

The Lafayette and Columbia formations contain occasional ledges of ferruginous sandstones and conglomerates that have furnished a poor grade of building stone for foundation purposes.

PEAT.

The term peat is applied to a dark-colored nearly black deposit formed by the accumulation and slow decay of vegetable matter under water in bogs and swamps. It is composed chiefly of partly decomposed and disintegrated vegetable matter. When impure and containing too much mineral matter to burn freely the black swamp deposits are more properly

called muck. The natural conditions most essential to the formation of peat are restricted access of air, and abundance of water.

When possessing a good degree of purity and properly prepared peat is a good and efficient fuel and may form the basis of a number of manufacturing industries. It has been used but little in America for fuel although repeated attempts have been made to so utilize it in Canada and New England. A large use of peat is in agriculture. Perhaps the largest use now made of peat in the United States is in the manufacture of fertilizer filler, which use seems to be a growing one. When used as a fertilizer, peat may be applied directly to the land or it may be used in composts. It is usually considered preferable, however, to compost the peat before its application to the land. Peat is of value as a fertilizer on account of its absorbent properties and nitrogen content, and because it adds to the humus and hence increases the water-retaining capacity of the soil. A great number of uses of peat other than those mentioned have been proposed, some of which have proved of little or no importance.

The Virginia Coastal Plain contains a very large acreage of swamp lands and some of these swamps contain peat. The most extensive one of these is the Great Dismal Swamp in Virginia and North Carolina, which lies on a fine sandy soil with an approximate slope of about 20 inches to the mile, and is covered by a thick layer of peaty matter. The extent and quality of the peaty matter in the swamps of eastern Virginia are unknown, since these lands have not yet been made the subject of detailed study or investigation.

The Dismal Swamp has been described in considerable detail by Mr. N. H. Darton[a] in the Norfolk folio, and is given on pages 56 to 58 of this volume. The vegetable accumulations of the Dismal Swamp are described by Darton as follows:

"The swamps lie in shallow basins in the surface of the general terrace of the Norfolk region. The basins are now filled to the general level of the surrounding country with vegetable accumulations, which have a maximum thickness of about 20 feet. In recent excavations for a gate on the feeder about half a mile east of Lake Drummond there were exposed 10 feet of peat filled with roots and tree trunks, lying on 8 feet of clear peat which merged with the overlying beds, and this in turn was underlain by fossiliferous sand of late Neocene age. The thickness of the swamp deposits decreases toward the periphery of the present swamp area, but so

[a]Norfolk Folio, No. 80, U. S. Geol. Survey, 1902.

few excavations have been made along the border zone that the conditions of thinning are not known. The upper beds of peaty materials merge gradually into the sands of the adjoining area, so that no boundary line can be given."

Ries[a] quotes the following proximate analysis of peat from the Dismal Swamp in Virginia:

Analysis of peat from the Dismal Swamp, Va.

	Per cent.
Moisture	20.22
Volatile matter	52.31
Fixed carbon	24.52
Fuel ratio	.47

Peat deposits of Pleistocene (Talbot) age are known at numerous points along the Potomac, Rappahannock, and James rivers, in the Virginia Coastal Plain. About 1 mile above Tappahannock, the Rappahannock River has cut into an old Talbot swamp deposit, exposing peat and many upright cypress stumps in an excellent state of preservation. A section is given of this deposit on page —, which shows compact brown to black peat containing numerous cypress stumps and knees in place, etc., of from 1 to 4½ feet in thickness. Buried swamp deposits of Pleistocene age are reported exposed in places by the recent wave-cutting along the western shores of Chesapeake Bay.

Although peat of commercial value may not be found in many of the swamps and bogs of the Coastal Plain, the winning of these lands to the uses of agriculture by dewatering, will afford fertile and productive fields. According to Professor Shaler, the quality of the soil is good and its endurance under cultivation is continuous. The vast acreage of swamp lands in eastern Virginia which at present are practically valueless are so located with reference to the sea that they may be effectively dewatered and won to the uses of agriculture at very considerable profit, in the future.

The proposed drainage of these lands in North Carolina has taken definite shape, and the question is very properly being seriously considered in Virginia, as is indicated by the passage of the Lesner bill by the last General Assembly and by a drainage meeting held at the State Capitol in Richmond on December 15, 1910.

[a]Ries, H. Economic Geology, 1910, new and revised edition, p. 6.

UNDERGROUND WATERS.

This subject is comprehensively treated in the report on "Underground Waters" of the Virginia Coastal Plain, published as Bulletin V of the Virginia Geological Survey, hence only a brief statement is here made regarding this very important resource.

The water supply of the Virginia Coastal Plain is secured from both shallow and deep wells, and water from both sources is obtainable in almost all parts of the region. The shallow water is found at the base of the Lafayette and Columbia formations at depths ranging from 15 to 60 feet. Most of the region is dependent upon this shallow water, which is generally pure though sometimes contaminated with surface drainage. It rarely contains much mineral matter in solution. The supply of water in these wells is seldom great but is usually sufficient for ordinary domestic purposes except in seasons of excessive drought.

The deep wells of the Coastal Plain furnish uncontaminated water, but much of it is so highly charged with saline materials that it is unserviceable. This is particularly the case in the vicinity of the Bay and Ocean. The deep wells may be divided into two classes, flowing and non-flowing wells. Except in the extreme western portion of the Coastal Plain practically the entire region is underlain by water-bearing strata from which the water will rise from 1 to 20 feet above tide. As a result flowing wells can be usually obtained in the low lands bordering the estuaries. Such wells are very common along the Potomac, Rappahannock, York, and James rivers. The same horizons furnish water for the deep wells over the divides but there the water does not rise to the surface.

The water-bearing horizons of the deep wells are numerous, the lowest of which occurs at the base of the Patuxent formation where it is in contact with the underlying crystalline floor. These basal beds furnish the water supply for many of the wells in Alexandria, but in the central and eastern portions of the region they have seldom been reached. From the western edge of the Coastal Plain this crystalline floor slopes gently to the eastward, and at Fortress Monroe lies 2246 feet beneath the surface. At that point no water was found at the exact contact of the Patuxent deposits with the crystalline rocks, but a supply of salty water was obtained in a coarse sand bed about 15 feet above. In all probability a good supply of water could be obtained almost everywhere at or near the contact in the central and western portions of the region and would not contain enough salt there to render it objectionable.

The Potomac deposits contain many coarse sandy strata above the basal beds and these almost invariably carry water. The variability of the beds, however, does not permit of the correlation of the water-bearing horizons except in very closely contiguous regions.

The Eocene beds of Virginia contain some coarse sand strata, which usually carry considerable water in the central part of the Coastal Plain. The flowing wells at Colonial Beach obtain a large supply of fine water from these strata at a depth of 250 feet, while the Eocene beds at Naylor's Wharf furnish an ample supply at depths ranging from 275 to 325 feet.

The Miocene formations contain many artesian water horizons which produce flowing wells along the larger streams. According to Darton these waters underlie a belt of country about 20 miles in width lying to the east of a line extending from Mathias Point on the Potomac River to Emporia. Miocene waters can also be obtained to the east of this belt, but they are so apt to be heavily charged with salt that it is usually advisable to seek water in deeper strata.

SOILS.

In the Coastal Plain of Virginia there is a great variety of soil types, each possessing special adaptability to certain crops. The region is strictly an agricultural one, consequently great interest is attached to the character of the soils. The soils of a region are formed from the surface portions of the underlying geological formations with which is mixed more or less humus from decaying vegetation. For example, the soils formed from the greensands of the Eocene are distinctive and very unlike those formed from the diatomaceous earth beds of the Miocene. On account of the greater or less diversity in the deposits of a single formation it will not everywhere, however, give rise to the same kind of soil. The Calvert formation, for example, embraces all the deposits formed during a certain period of submergence including clays, sands, diatomaceous earth, and shell beds. The soils formed from the deposits of this formation will therefore vary as much as the strata from which they are derived. Furthermore, the same soil types may be produced from geological formations of different age. It is important then to study in great detail the stratigraphy of the various formations, in order fully to interpret the soils.

The soils of the Coastal Plain are, for the most part, derived from the Lafayette and Columbia formations which appear at the surface over much the larger portion of Tidewater Virginia. The character of these beds, however, is so largely dependent upon the underlying strata that indirectly

the older formations affect the character of the soils even where they do not appear at the surface.

Sands, clays, loams, and gravels constitute largely the surface materials and from these most of the soils have been derived. The United States Bureau of Soils has differentiated a great many soil types in the Coastal Plain but these may be classed under four heads—clay soils, loam soils, sand and gravel soils, and swamp and flood-plain soils.

The heavy clay soils form a narrow belt in the northwestern part of the Coastal Plain, being well developed trom Fredericksburg to Washington. The soils which are plastic and usually red in color are formed from the Potomac deposits and are of little value for agricultural purposes. Most of the region is covered with scrub pine though some areas are under cultivation. Cucumbers can be raised more profitably on this type of soil than almost any other crop and to the north of Fredericksburg they are extensively grown.

The loam soils include those soil types which are more specifically referred to as the clay loams and sandy loams. The former are very extensively developed over the divides in the central and western portions of the Coastal Plain and occur in smaller areas in the eastern parts of the region. These soils are formed from the clay loam facies of the Lafayette and Columbia deposits and are among the most productive soils of the region. They are well adapted to the cultivation of grass, hay, small grain and corn. They are less productive in regions where the sand constitutes a large part of the soils producing a sandy loam and such areas are usually covered with pine forests.

The soils largely composed of sand have their greatest development in the extreme eastern part of the State and although naturally less productive than the loam soils are yet far more important because of the early maturity of the crops. The great trucking regions of the State occupy the eastern portion of the Coastal Plain and here are grown enormous quantities of early vegetables and potatoes for the Washington, Baltimore, Philadelphia, New York, and Boston markets. In some places the soil itself is considered as little more than a medium in which the artificial fertilizers can be held, as the nourishment for the plants consists almost entirely of these added products. The loose open textures of the soils permit easy underground drainage which tends to hasten the maturity of the crops.

The swamp and flood-plain soils constitute several distinct soil types in which there is a large admixture of vegetable humus. These are the richest soils of the Coastal Plain and are developed on the low lands

bordering the streams and Chesapeake Bay. Large crops are grown on these soils which are especially adapted to corn and hay. Vegetables of all kinds thrive and attain a greater size than those grown in the sandy soils but as late truck does not command good market prices few vegetables are raised on these soils.

The United States Bureau of Soils has mapped and described the soils of four areas within the Coastal Plain of Virginia that are widely separated, namely, Norfolk,[a] Hanover County,[b] Yorktown,[c] and Chesterfield County.[d] The numerous soil types represented in the four areas may be considered as typical of the soils in general of the Coastal Plain. The texture of typical samples of the soils and subsoils mapped and described by the Bureau of Soils is shown in the tables of mechanical analyses below.

Twelve types of soils are differentiated in the Hanover County Survey. Of these, four (Cecil sandy loam, Cecil clay, Cecil sand, and Meadow) belong to the Piedmont portion of the area surveyed, and the remaining eight to the Coastal Plain.

Areas of different soils.

Soil	Acres	Per cent.
Cecil sandy loam	97,856	32.2
Norfolk sandy loam	88,256	29.0
Norfolk fine sandy loam	39,232	12.9
Cecil sand	29,696	9.8
Meadow	15,552	5.1
Cecil clay	7,360	2.4
Leonardtown loam	6,784	2.2
Swamp	6,208	2.1
Wickham sandy loam	5,120	1.7
Wickham sand	4,416	1.4
Wickham clay loam	2,176	.7
Norfolk gravelly loam	1,344	.5
Total	304,000	....

[a]Lapham, J. E. Soil Survey of the Norfolk Area, Virginia. U. S. Dept. of Agl., Bureau of Soils, 1903 (1904), Fifth Report, pp. 233-252.

[b]Bennett, H. H. and McLendon, W. E. Soil Survey of Hanover County, Virginia. Idem. 1905 (1907), Seventh Report, pp. 213-245.

[c]Burke, R. T. Avon and Root, A. S. Soil Survey of the Yorktown Area, Virginia. Idem. 1905 (1907), Seventh Report, pp. 247-270.

[d]Bennett, F., Winston, R. A., Geib, W. J., and Mann, C. W. Soil Survey of Chesterfield County, Virginia. Idem. 1906 (1908), Eighth Report, pp. 195-222.

The following tables give the average results of mechanical analyses of the seven types of soil differentiated by the Bureau of Soils in Hanover County:

Mechanical analyses of Norfolk sandy loam.

Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Soil	1.0	14.7	14.1	35.5	13.0	14.1	6.6
Subsoil	.7	8.3	10.9	34.0	12.7	14.7	18.5

Mechanical analyses of Norfolk fine sandy loam.

Soil	0.4	3.6	5.5	28.4	26.2	27.9	7.8
Subsoil	.4	3.0	4.5	24.0	20.2	24.8	23.0

Mechanical analyses of Wickham clay loam.

Soil	0.8	3.4	4.5	27.3	24.7	22.2	16.4
Subsoil	.3	1.4	2.6	15.9	21.8	24.3	33.7

Mechanical analyses of Wickham sandy loam.

Soil	2.2	16.1	15.5	23.5	13.6	16.8	12.0
Subsoil	1.5	13.0	14.3	21.2	10.9	15.7	23.2

Mechanical analyses of Wickham sand.

Soil	7.1	30.8	12.4	16.7	13.0	10.6	9.2
Subsoil	6.3	27.8	13.4	18.9	13.0	10.2	10.2

Mechanical analyses of Norfolk gravelly loam.

Soil	6.9	19.4	18.8	21.1	6.8	19.0	7.7
Subsoil	8.7	27.5	13.4	17.4	4.6	8.0	20.2

Mechanical analyses of Leonardtown loam.

Soil	1.4	6.8	5.2	21.3	19.4	27.2	18.6
Subsoil	.9	6.2	4.9	17.9	17.9	22.7	28.9

Eleven types of soils are differentiated by the Bureau of Soils in the Yorktown area, which range in texture from clay and silt to fine gravel, with the predominating types consisting of fine to medium sandy loams. The following table gives the names and extent of the several soils in the area surveyed.

Areas of different soils.

Soil	Acres	Per cent.
Norfolk fine sandy loam	144,064	37.6
Norfolk sandy loam	94,016	24.5
Leonardtown loam	36,800	9.6
Portsmouth fine sandy loam	29,760	7.8
Swamp	26,368	6.9
Galveston clay	21,568	5.7
Portsmouth sandy loam	20,032	5.2
Norfolk coarse sandy loam	4,288	1.1
Portsmouth clay loam	2,176	.6
Galveston sand	1,984	.5
Norfolk clay loam	1,856	.5
Total	382,912	....

The following tables give the average results of mechanical analyses of the eleven types of soils mapped and described by the Bureau of Soils.

Mechanical analyses of Portsmouth fine sandy loam.

Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Soil	0.4	3.1	6.5	47.9	7.3	21.1	13.5
Subsoil	.2	2.2	4.2	32.8	9.2	27.4	21.5

Mechanical analyses of Norfolk clay loam.

Soil	1.0	3.2	7.6	22.6	7.1	34.8	23.9
Subsoil	.5	3.6	6.1	17.8	6.9	32.2	32.9

Mechanical analyses of Portsmouth clay loam.

Soil	0.1	1.3	4.5	26.5	7.7	38.4	21.3
Subsoil	.2	1.9	4.9	28.7	4.8	38.2	21.0

Mechanical analyses of Portsmouth sandy loam.

Soil	0.9	5.9	14.4	39.2	16.8	14.6	7.9
Subsoil	.5	5.1	12.0	38.4	4.7	16.9	22.1

Mechanical analyses of Leonardtown loam.

Soil	0.7	3.9	4.5	21.9	14.7	42.2	13.7
Subsoil	.9	2.2	3.2	17.3	9.4	36.3	29.1

Mechanical analyses of Norfolk coarse sandy loam.

Soil	16.4	27.9	8.9	12.2	2.5	18.7	13.0
Subsoil	16.3	30.0	8.2	7.9	1.9	19.8	15.1

Mechanical analyses of Norfolk sandy loam.

Soil	0.4	9.4	13.8	46.3	10.3	11.3	7.6
Subsoil	.9	10.0	13.1	38.6	11.1	12.6	13.6

Mechanical analyses of Norfolk fine sandy loam.

Soil	2.2	4.8	9.9	39.6	10.2	25.5	9.3
Subsoil	3.2	4.3	8.6	33.9	8.0	24.0	20.5

Mechanical analyses of Galveston sand.

Soil	0.8	19.8	21.8	49.9	1.7	3.4	2.5
Subsoil	1.6	22.8	26.7	36.0	2.4	6.6	3.7

The Bureau of Soils has recognized and mapped in the Norfolk area seven distinct types of arable soils, and two nonarable types (Galveston sand and Swamp). The table below gives the area and extent of each of these types.

Areas of different soils.

Soil	Acres	Per cent.
Leonardtown loam	53,952	27.8
Norfolk fine sandy loam	38,144	19.7
Portsmouth sandy loam	30,016	15.4
Norfolk loam	23,872	12.3
Norfolk sand	20,864	10.7
Swamp	12,928	6.7
Galveston sand	10,752	5.5
Portsmouth sand	2,048	1.1
Leonardtown gravelly loam	1,536	.8
Total	194,112	....

Of the seven arable types of soils in the Norfolk area, six (Leonardtown loam, Norfolk fine sandy loam, Portsmouth sandy loam, Norfolk loam, Norfolk sand, and Portsmouth sand) are good trucking soils, while the remaining one (Leonardtown gravelly loam) is best adapted to the growth of ordinary farm crops.

The tables below show the texture of typical samples of the soil and subsoil of the seven arable types mapped and described by the Bureau of Soils in the Norfolk area.

Mechanical analyses of Norfolk sand.

Locality	Description	Organic Matter.	Gravel, 2 to 1 mm.	Coarse Sand, 1 to 0.5 mm.	Medium Sand, 0.5 to 0.25 mm.	Fine Sand, 0.25 to 0.1 mm.	Very Fine Sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent	Per cent.
¼ mile W. of West Norfolk	Brown medium sand, 0 to 12 inches	1.60	0.20	4.64	17.86	46.96	4.32	18.92	6.88
1½ miles N. of Belleville	Brown medium sand, 0 to 12 inches	.36	.04	1.22	7.52	55.90	13.96	14.18	7.16
1 mile SW. of Niles	Brown sand, 0 to 12 inches	.92	.02	1.16	4.30	55.22	12.70	18.14	8.24
Subsoil of 8702	Loose yellow sand, 12 to 36 inches	.50	.04	.46	4.12	56.80	15.50	15.52	7.46
Subsoil of 8704	Yellow medium sand, 12 to 30 inches	.83	.10	4.42	17.10	44.70	3.92	20.24	9.52
Subsoil of 8700	Loose to plastic sand, 12 to 36 inches.	.31	.04	.50	7.28	47.42	13.28	19.20	12.22

Mechanical analyses of Norfolk fine sandy loam.

Locality	Description	Organic Matter.	Gravel, 2 to 1 mm.	Coarse Sand, 1 to 0.5 mm.	Medium Sand, 0.5 to 0.25 mm.	Fine Sand, 0.25 to 0.1 mm.	Very Fine Sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
½ mile NE. of Oceana	Medium sandy loam, 0 to 11 inches	0.87	1.34	21.14	21.90	15.84	5.66	26.64	7.46
2 miles SW. of Churchland	Medium sandy loam, 0 to 11 inches	1.33	.00	.54	4.76	54.62	13.42	18.14	8.52
2 miles W. of West Norfolk	Medium sandy loam, 0 to 12 inches	1.63	.28	2.34	11.70	52.74	7.60	16.46	8.62
Subsoil of 8708	Sand to sandy loam, 12 to 36 inches	.21	.22	2.06	11.32	46.62	5.50	23.42	10.78
Subsoil of 8706	Fine sandy loam, 11 to 36 inches	.29	.10	.26	4.30	53.64	12.40	17.32	11.74
Subsoil of 8710	Fine sandy loam, 11 to 36 inches	.40	.96	16.74	21.90	14.72	3.00	27.88	14.70

Mechanical analyses of Portsmouth sandy loam.

Locality	Description	Organic Matter.	Gravel, 2 to 1 mm.	Coarse Sand, 1 to 0.5 mm.	Medium Sand, 0.5 to 0.25 mm.	Fine Sand, 0.25 to 0.1 mm.	Very Fine Sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
5 miles SW. of Portsmouth	Fine black loam, 0 to 12 inches	7.01	0.16	1.50	21.68	32.04	3.20	28.10	12.04
½ mile E. of Churchland	Sandy loam, 0 to 8 inches	2.84	.06	1.46	5.80	55.40	6.50	18.42	12.36
Subsoil of 8716	Silty fine sand, 12 to 36 inches	.58	.00	.70	24.22	36.74	2.10	21.38	14.86
Subsoil of 8714	Sticky sandy loam, 8 to 36 inches	1.04	.12	.68	3.30	53.06	6.94	18.74	17.14

Mechanical analyses of Norfolk loam.

Locality	Description	Organic Matter.	Gravel, 2 to 1 mm.	Coarse Sand, 1 to 0.5 mm.	Medium Sand, 0.5 to 0.25 mm.	Fine Sand, 0.25 to 0.1 mm.	Very Fine Sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
1 mile NW. of Herbert	Fine sandy loam, 0 to 9 inches	0.89	0.60	3.24	12.82	37.94	11.14	27.68	6.58
2 miles NW. of Jacksondale	Fine sandy loam, 0 to 12 inches	1.79	.50	5.70	18.12	27.16	3.56	35.02	9.62
1 mile SW. of Virginia Beach	Brown sandy loam, 0 to 12 inches	1.94	.28	8.90	16.14	16.58	5.44	42.20	9.66
Subsoil of 8684	Fine sandy loam, 12 to 36 inches	.48	.50	4.46	17.20	26.04	3.08	36.14	12.18
Subsoil of 8686	Yellow sandy loam, 9 to 36 inches	.38	.28	1.54	9.06	27.84	8.70	35.32	16.98
Subsoil of 8682	Fine sandy loam, 12 to 36 inches	.56	.52	6.80	14.34	13.96	3.70	40.28	20.38

Mechanical analyses of Leonardtown loam.

Locality	Description	Organic Matter	Gravel, 2 to 1 mm.	Coarse Sand, 1 to 0.5 mm.	Medium Sand 0.5 to 0.25 mm.	Fine Sand, 0.25 to 0.1 mm.	Very Fine Sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
		Per cent	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1 mile SE. of Kempsville	Gray silty loam, 0 to 9 inches	1.84	0.58	1.34	2.48	12.76	5.10	66.86	10.82
1 mile N. of Princess Anne C. H.	Fine silty loam, 0 to 9 inches	2.17	.10	1.14	2.44	4.28	6.22	69.66	16.16
1½ miles NW. of Sigma	Fine gray silt, 0 to 9 inches	2.76	.06	.42	.46	1.82	8.94	68.60	19.70
Subsoil of 8696	Fine gray silt, 9 to 36 inches	.35	.00	.10	.20	1.30	7.66	70.98	19.76
Subsoil of 8694	Silt, 9 to 36 inches	.81	.16	.80	1.56	7.48	3.44	57.00	29.56
Subsoil of 8692	Gray silty loam, 9 to 36 inches	.47	.04	.46	.90	1.32	5.80	58.70	32.56

Mechanical analyses of Loanardtown gravelly loam.

3½ miles NE. of Waterworks	Gray silty loam, 0 to 9 inches	2.54	12.02	9.94	3.68	4.76	4.84	48.24	16.46
Subsoil of 8698	Gray silty loam, 9 to 36 inches	.45	18.54	19.38	3.62	5.00	6.88	28.74	17.72

Mechanical analyses of Portsmouth sand.

1¾ miles SW. of Portsmouth	Coarse gray sand, 0 to 12 inches	1.55	0.18	4.66	57.46	31.40	1.20	3.30	1.38
3½ miles SW. of Portsmouth	Coarse gray sand, 0 to 10 inches	2.71	.06	3.62	50.50	31.72	1.34	6.26	6.50
Subsoil of 8688	Coarse sand, 12 to 36 inches	.42	.16	5.80	50.38	37.14	1.80	2.90	1.82
Subsoil of 8690	Brown medium sand, 10 to 36 inches	1.77	.10	2.52	49.98	31.00	1.36	7.06	7.98

Twelve soil types are differentiated by the Bureau of Soils in the Chesterfield County Survey. The soils are described as being light-textured sands, sandy loams, and loams. About four-fifths of the mapped area lies within the Piedmont region and the principal soils are Chesterfield gravelly sandy loam, Chesterfield sandy loam, and Bradley sandy loam. The principal Coastal Plain soil types represented include the Norfolk sand, the Norfolk sandy loam, and the Norfolk fine sandy loam.

There is given in the table below the name and extent of the twelve soil types mapped in the Chesterfield County area.

Areas of different soils.

Soil	Acres	Per cent.
Chesterfield sandy loam	95,680	31.1
Bradley sandy loam	59,072	19.3
Chesterfield gravelly sandy loam	34,304	11.2
Norfolk sandy loam	32,704	10.7
Meadow	25,088	8.2
Elkton fine sandy loam	14,656	4.8
Norfolk sand	11.200	3.7
Congaree loam	9,984	3.3
Norfolk fine sandy loam	8.832	2.9
Norfolk silt loam	5,952	2.0
Wickham loam	5,952	2.0
Swamp	2,432	0.8
Total	305,856	....

The tables below give the average results of mechanical analyses of the principal Coastal Plain soil types in the area mapped, which are the Norfolk sand, the Norfolk sandy loam, and the Norfolk fine sandy loam.

Mechanical analyses of the Norfolk fine sandy loam.

Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Soil	0.6	3.6	4.7	23.1	20.3	40.1	7.5
Subsoil	.1	2.1	2.7	16.0	12.2	35.9	30.7

Mechanical analyses of Norfolk sandy loam.

Soil	2.5	21.9	16.9	24.7	6.9	20.9	6.1
Subsoil	1.7	17.0	9.4	19.7	7.7	20.1	24.1

Mechanical analyses of Norfolk sand.

Soil	2.6	18.3	12.1	31.5	10.8	18.8	5.2
Subsoil	4.2	23.0	11.5	29.9	9.5	15.6	6.4

Darton[a] gives the following description of the swamp soils in the Norfolk quadrangle.

"The soils of the swamps vary from pure peat to clayey loam. Two leading varieties are recognized, the 'Juniper' or 'light' swamp, and the 'black gum' or 'dark' swamp. The first is nearly pure peat, consisting of a brown mass of vegetal fragments derived from the juniper or white cedar, which is the characteristic tree of 'light' swampy areas. The thickness of the deposit is often 8 to 10 feet. From 75 to 95 per cent of the material is organic. When such land is cleared and drained the peat cakes and hardens so that it resembles charred wood. Land of this sort is practically worthless. The black gum swamp deposits which have been laid down in various portions of the Dismal and other swamps and which bear a forest of cypress, black gum, and red maple, are well adapted to agriculture in most cases. This soil contains a large amount of organic matter which is mainly in its upper portion. When it is properly drained and cultivated the amount of organic matter gradually diminishes, but it has been found in the drained areas that after being under cultivation for fifty years the soil still retains enough organic matter to remain black in color. The organic matter furnishes nitrogenous materials to plants, so that the soil is a rich one, but its disposition to retain moisture renders it rather slow for the raising of early vegetables. The soils are also notably acid, which has to be neutralized by repeated applications of lime. The percentage of clay in the swamp soils is large, for the sluggish drainage in the swampy areas does not bring much sand, and the principal inorganic sediments are very fine flocculent clayey materials. This character greatly retards artificial drainage of the region, so that in reclaiming swamp lands numerous ditches and extensive tiling are necessary * * * *. There are extensive areas of the swamp which can be economically drained and which have rich and lasting soils, and the region has good prospects of being valuable agriculturally in the future. It is not expected that the soils will be available for truck farming to the same extent as the dry plains of the surrounding region, but they will yield crops of many important staples."

[a]Norfolk Folio, No. 80, U. S. Geol. Survey, 1902, p. 4.

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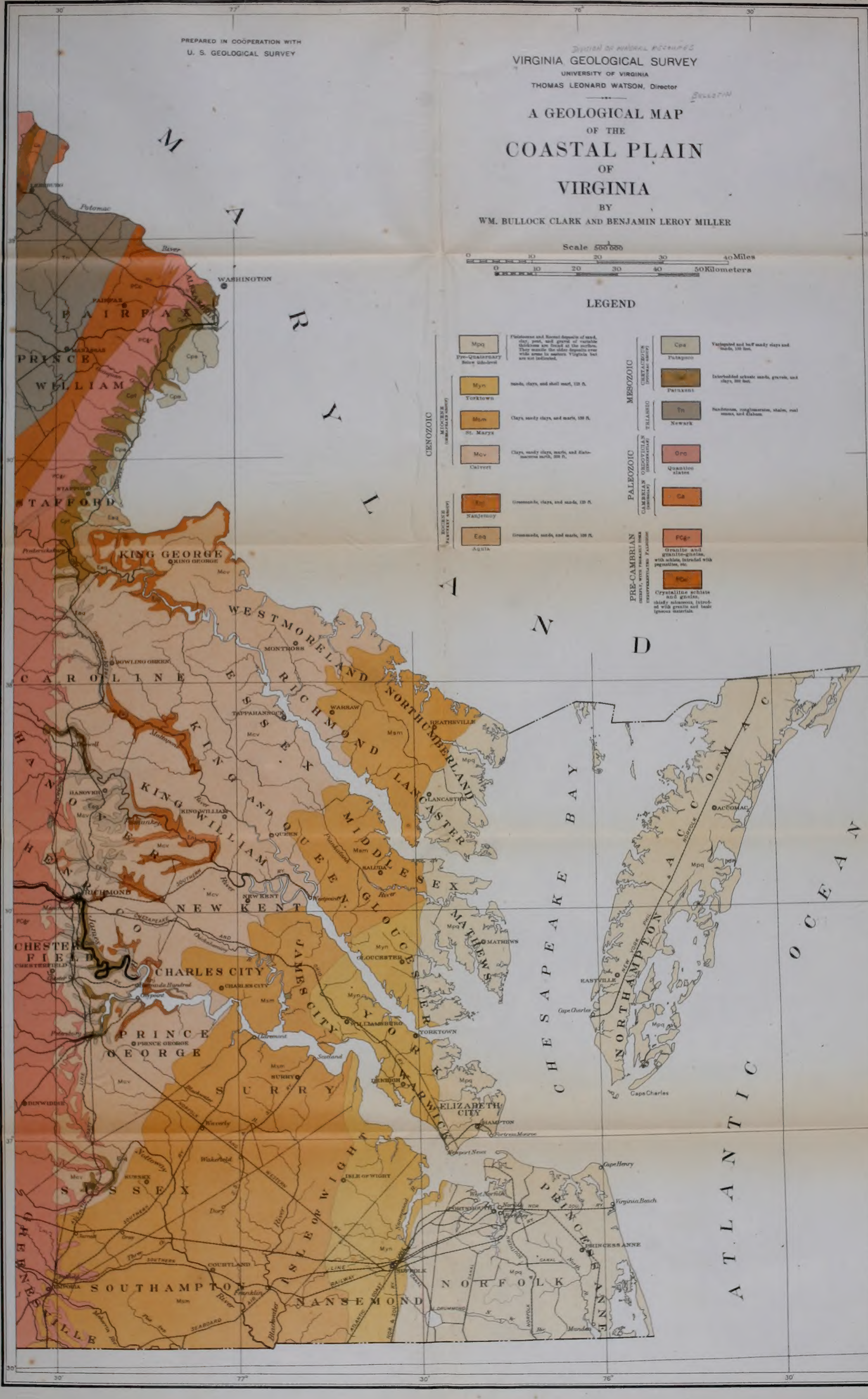
PREPARED IN COOPERATION WITH
U. S. GEOLOGICAL SURVEY
VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA
THOMAS LEONARD WATSON, Director
A GEOLOGICAL MAP
OF THE
COASTAL PLAIN
OF
VIRGINIA
BY
WM. BULLOCK CLARK AND BENJAMIN LEROY MILLER
Scale 1/500 000
0 10 20 30 40 Miles
0 10 20 30 40 50 Kilometers
LEGEND
CENOZOIC
MIOCENE
EOCENE
Mpq
Pre-Quaternary
Myn
Yorktown
Msm
St. Marys
Mcv
Calvert
Nanjemoy
Eaq
Aquia
MESOZOIC
CRETACEOUS
TRIASSIC
Cpa
Patapsco
Patuxent
Tn
Newark
PALEOZOIC
ORDOVICIAN
CAMBRIAN
Orc
Quantico slates
Ca
PRE-CAMBRIAN
Granite and granite-gneiss, with schists, intruded with pegmatites, etc.
Crystalline schists and gneiss, chiefly micaceous, intruded with granite and basic igneous materials.
M A R Y L A N D
CHESAPEAKE BAY
ATLANTIC OCEAN
WASHINGTON
FAIRFAX
PRINCE WILLIAM
STAFFORD
KING GEORGE
WESTMORELAND
NORTHUMBERLAND
RICHMOND
LANCASTER
CAROLINE
ESSEX
MIDDLESEX
KING AND QUEEN
KING WILLIAM
HANOVER
HENRICO
NEW KENT
GLOUCESTER
MATHEWS
CHESTERFIELD
CHARLES CITY
JAMES CITY
YORK
WARWICK
ELIZABETH CITY
PRINCE GEORGE
SURRY
SUSSEX
ISLE OF WIGHT
SOUTHAMPTON
NANSEMOND
NORFOLK
PRINCESS ANNE
GREENSVILLE
ACCOMAC
NORTHAMPTON
RICHMOND
HANOVER
KING GEORGE
BOWLING GREEN
TAPPAHANNOCK
WARSAW
MONTROSS
HEATHSVILLE
LANCASTER
SALUDA
GLOUCESTER
MATHEWS
YORKTOWN
WILLIAMSBURG
HAMPTON
NORFOLK
PRINCESS ANNE
ACCOMAC
EASTVILLE
Cape Charles
Cape Henry
Virginia Beach
Fortress Monroe
Newport News
SURRY
COURTLAND
DINWIDDIE
PRINCE GEORGE
CHARLES CITY
CHESTERFIELD
ISLE OF WIGHT
SUSSEX
Potomac River
James
Rappahannock
Mattapony
Pamunkey
Chickahominy
Blackwater
Nottoway
Meherrin
Scotland
Claremont
Wakefield
Waverly
Franklin
Petersburg
Fredericksburg